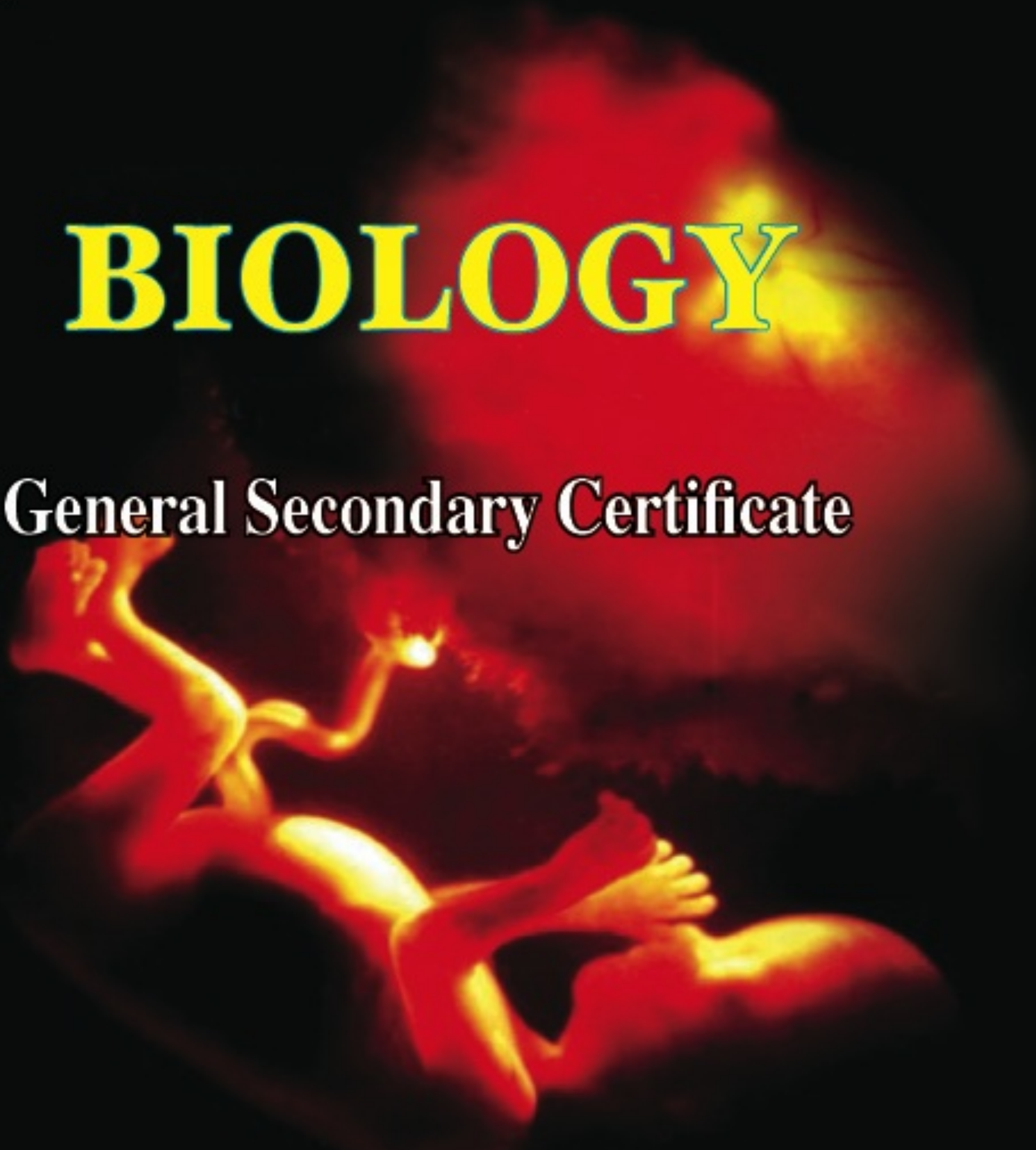
Arab Republic of Egypt
Ministry of Education
Book Sector

BIOLOGY

General Secondary Certificate



2016 _ 2017

غير مصرح بتداول هذا الكتاب خارج وزارة التربية والتعليم

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General Secondary Certificate

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2016 - 2017

غير مصرح بتداول هذا الكتاب خارج وزارة التربية والتعليم

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تقـديـم

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فقد تفضل الأستاذ الدكتور وزير التربية والتعليم بإعطاء توجيهاته لتطوير كتاب الأحياء ليفى بتحقيق أهداف مادة الأحياء دون تكرار أو تزايد فى تفاصيل غير جوهرية.

وقد كلف الأستاذ الدكتور وزير التربية والتعليم بتشكيل فريق عمل من أساتذة الجامعات لإنجاز هذه المهمة، وذلك بالتنسيق والتعاون مع موجهى وخبراء من الوزارة ومن الميدان، وبمشاركة بعض مؤلفى الكتاب.

وهكذا يظهر كتاب الأحياء فى شكله المطور، والذى نتمنى أن يساعد الطلاب والطالبات على استيعاب محتواه، ويحقق لهم النجاح والتفوق.

ونتمنى أن يحقق الكتاب بصورته الجديدة النجاح لأبنائنا..

والله ولى التوفيق

لجنة التطوير

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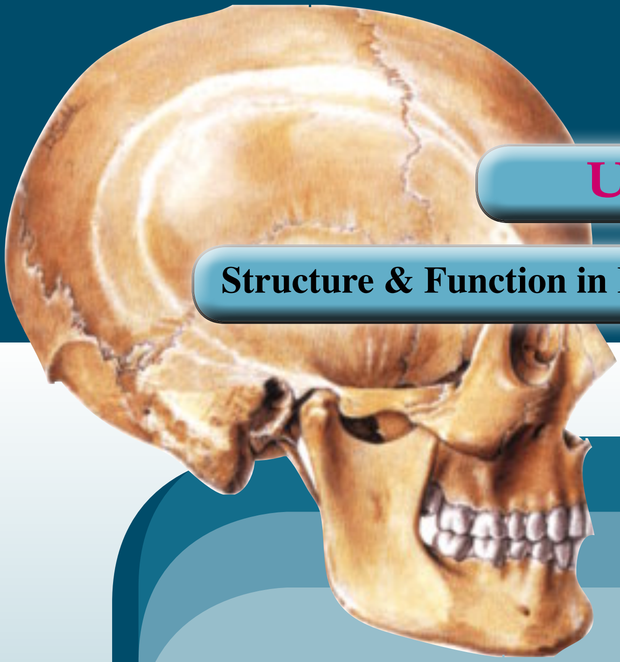
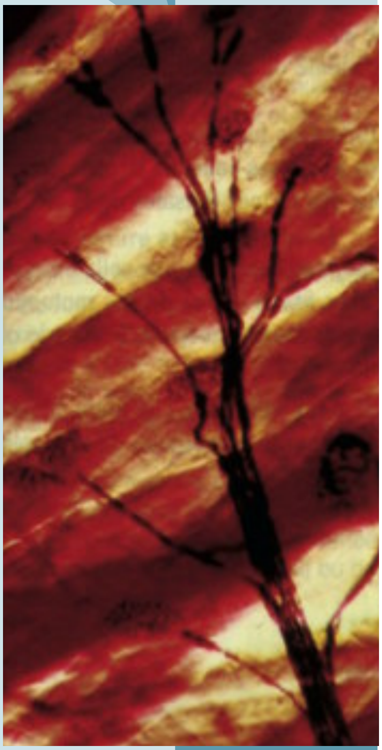


Unit One

Structure & Function in Living Organisms

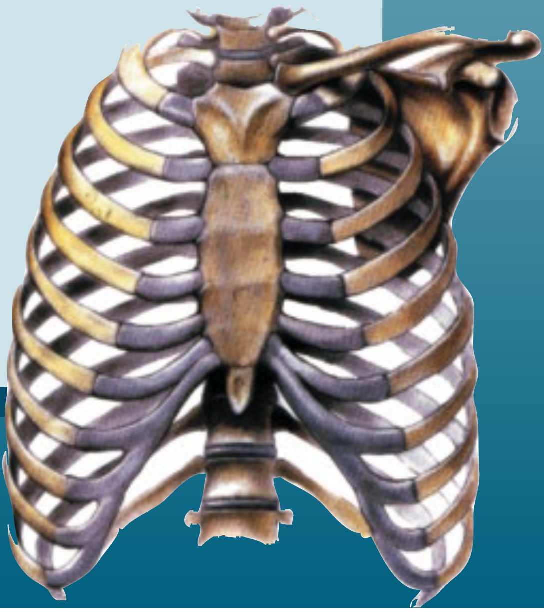
Chapter One

Support and movement in living organisms



At the end of this chapter, the student should be able to :

- Recognize the concept of movment in living organisms.
- Recognize the concept of support in living organisms.
- Explain the reason of twining tendrils around the support.
- Differentiate between pulling movememt by tendrils and pulling roots of corms and bulbs.
- Mention the functions of muscular system in man.
- Recognize the structure of muscle.
- Explain the mechanism of movement in man.
- Acquire an experience in:
  a) Drawing the vertebra.
  b) Microscopic examination of cytoplasmic movement in the cells of Elodea leaf.
  c) Link between structure and function of both skeletal system and muscular system.



Support and movement in living organisms

Support in plants:

The plant possesses different methods and systems for support so as to maintain its shape and for protection. These methods may be physiological concerning the cell as a whole, or may be structural, as the deposition of hard substance cell on the wall or part of it such as cellulose and lignin on the cell wall or parts of it. The support depends on the position and distribution of these parts.

A) The physiological support

If you soak dried fruit in water you will notice, after a time, that it absorbs water, enlarges in size and swells, due to the turgidity of its cells. On the contrary, if you leave fresh seeds such as peas or beans, for a time, you will notice that the seeds become wrinkled and wilt due to loss of water from their cells, and so lose its swelling and tension.

We can say that the cell becomes turgid, when water passes by osmosis into its vacuoles. As a result, the size and pressure of vacuoles increase as a result the size and pressure increase which press in turn on the protoplasm pushing it to outside towards the wall which expand into to pressure affecting the shape of the cell wall.

As well as the wilting of leaves and stems of herbaceous plants that face duroght. The wilting plant will attain its turgidity by soil irrigation, due to turgidity of internal tissue cells

B) The structural support

The plant has many other methods for support such as the deposition of some substances on or in its cell walls. The external plant cells cannot prevent loss of water from the inner cells and so the epidermal cell walls become thick and impermeable due to cutin being deposited. The plant may surrounds itself by an impermeable cork layer containing suberin. Cellulose or lignin may be deposited on the cell walls or in some of its parts, so these cells become stronger, such as:

1. Collenchyma cells.
2. Sclerenchyma cells. (Fibers and Stone cells).

The location of these cells and its distribution support the plant.

The Skeletal System of Man

The skeletal system in man consists of skeleton, cartilages, joints, ligaments and tendons.

Firstly the skeleton of man: Consists of 206 bones each bone has a shape and a size that suitable for its function, the skeleton consists of an axis called the vertebral column attached at its upper end with the skull. The vertebral column is also connected to the thoracic cage and the fore limbs through the shoulder bones and to the lower limb through the pelvis bones. The skeleton can be divided into axial and appendicular skeleton.

The axial skeleton includes the skull and the vertebral column, while the appendicular skeleton includes pectoral girdle, fore (upper) limbs, pelvic girdle and hind (lower) limbs.

A) The axial skeleton consists of:

1) The vertebral column

It consists of 33 vertebrae it consists of 33 vertebrae divided to five groups different in shape according to the region which are 7 cervical articulating vertebrae (of moderate size), 12 thoracic articulating vertebrae (larger than cervical), 5 lumbar articulating vertebrae (the largest and face the abdominal region), 5 sacral vertebrae (broad, flat and fused tigether) and 4 coccigeal vertebrae (small and fused tigether) (Fig. 1).

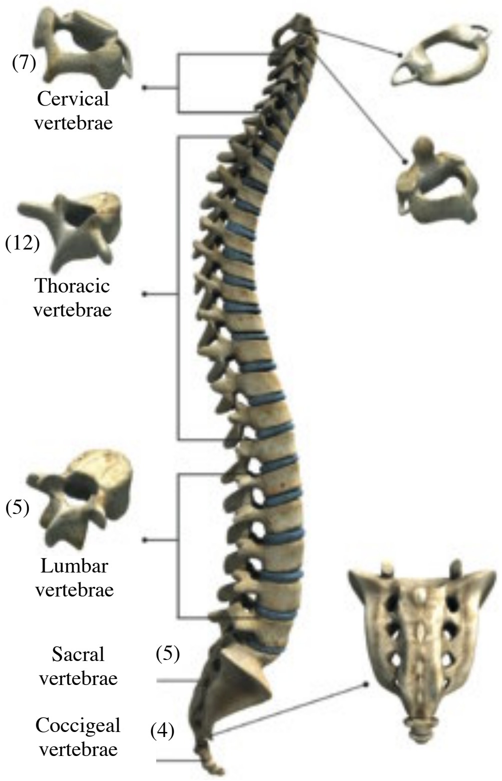


Fig. (1) The Vertebral column

The vertebral column acts as the main support of the body, protect the spinal cord and help in the movement of the head and the upper body parts.

The Structure of bony vertebra:

Each vertebra consists of an anterior thick part called the centrum, attached laterally with two transverse processes and attached posteriorly with a bony ring (spinal ring) carry a bony process directed downwards called neural spine (Fig. 2). The neural ring surrounds the neural canal in which the spinal cord extends to be protected.

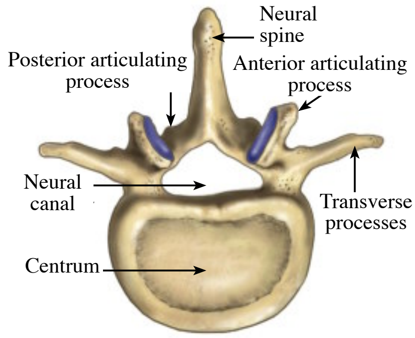


Fig. (2) The bony vertebra

2) The skull (cranium)

It is a bony case consists of:

1. The Posterior part (cerebral part) consists of 8 serrated bones attached firmly to each other to form a cavity to protect the brain.At the base of the skull there is a foramen magnum through which the spinal cord is connected to the brain (Fig. 3).
2. The Anterior part (facial part) includes face bones, the two jaws and the positions of sense organs (ears, eyes and nose).

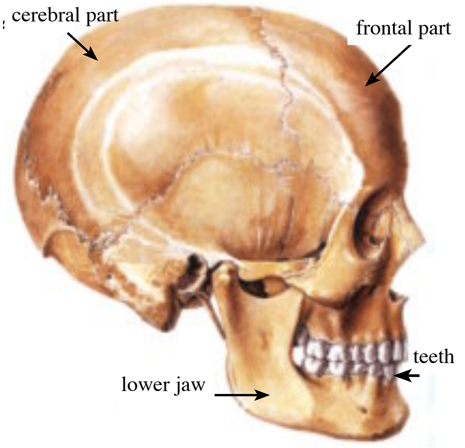


Fig. (3) The skull (cranium)

3) The thoracic cage:

A case, slightly conical in shape, connected posteriorly to the 12 thoracic vertebrae and anterioly to the sternum (a flat bone pointed at its lower part which is cartilaginous).

The thoracic cage consists of 12 pairs of ribs, all of them are connected posteriorly to the thoracic vertebra ,but the upper 10 pairs only are connected to the sternum anteriorly , the two lower pairs are short and do not reach the sternum so, they are called floating ribs, which are short and do not reach the sternum.

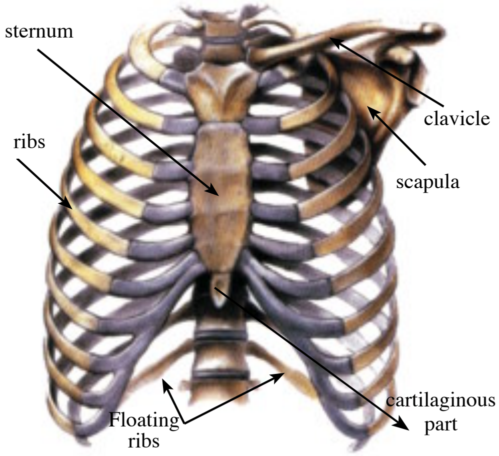


Fig. (4) The thoracic cage

The rib is a curved bone binds to down ward and attached posteriorly to the centrum of a vertebra and its transverse process.

During inspiration the ribs move anteriorly and laterally to increase the volume of the thoracic cavity and vice versa during expiration also it protects the heart and lungs.

(B) The appendicular skeleton

1) The pectoral girdle and the upper limbs:

The pectoral girdle consists of two identical halves. Each half consists of scapula which is a triangular dorsal bone, its inner end is broad while the outer end is pointed and has a process attached to the clavicle, which is a ventral thin bone.

At the outer end of the scapula there is a glenoid cavity through which the head of humerus fits in forming the shoulder joint.

Each upper limb consists of:

a) Upper arm supported by one bone called humerus.

b) Lower arm supported by two bones which are radius and ulna. The upper part of the ulna has a depression where the inner projection of the humerus fits. The radius is small in size and can rotate around a fixed ulna.

c) The wrist consists of 8 bones in two rows called carpals their upper ends are attached to the lower part of the radius, while their lower ends are attached to the bones of the hand Plam (Fig. 5).

d) The palm consists of 5 long thin bones called metacarpals followed by the ones of five digits each is made of 3 bones called phalanges except the thumb which consists of 2 phalanges only.

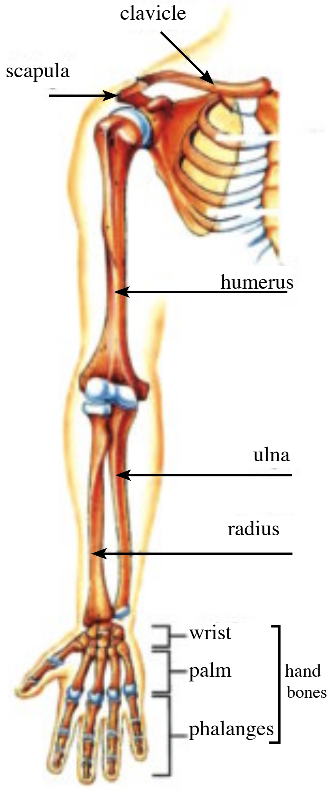


Fig. (5)
The upper (fore) limb

2) The pelvic girdle and the lower limbs:

The pelvic girdle consists of two identical halves fused at the ventral side at a region called the pubic symphysis (fig. 6).

Each half consists of a dorsal bone called ilium which is attached anteriorly and ventrally to a bone called pubis and attached posteriorly and ventrally to a bone called ischium. At the position of attachment of ilium and ischium bones there is a deep depression called acetabulum into which the head of the thigh bone (femur) fits and forming the hip joint.

Each lower limb consists of :

a) Thigh bone which is supported by a bone called femur.

b) Shank, supported by 2 bones, inner tibia and outer fibula.

At the lower end of femur there are two processes that articulate with the shank at the knee joint. Infront of the knee joint there is a small, round bone called the patella.

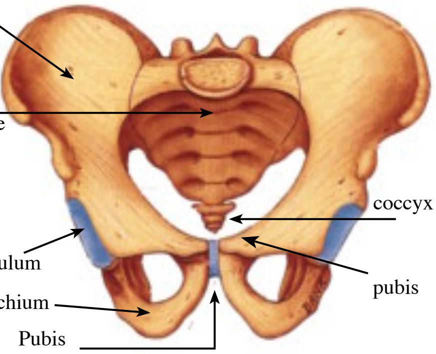


Fig. (6) The Pelvic girdle

c) The ankle consists of 7 bones irregular in shape called tarsals and the largest of which is that at the back which forms the heel.

d) The foot bones which consist of 5 bones called metatarsals which are long and thin and end with the bones of 5 toes each is made of 3 bones called phalanges except the big toe which has 2 phalanges only. (Fig. 7).

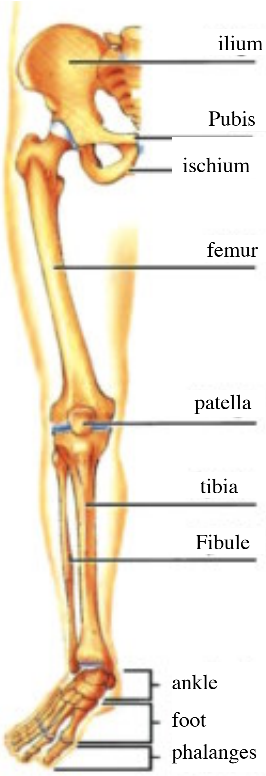


Fig. (7) Lower limb

Secondly Cartilages:

They are type of connective tissues, consists of cartilaginous cells and found usually at the tips of the bones especially at joints and between the vertebra of the vertebral column to protect the bones from corrosion due to continues friction. The cartilages forms some body parts as ears, nose, bronchioles of lungs. The cartilages do not contain blood vessels, so they get food and oxygen from the bone cells by diffusion.

Thirdly Joints:

In the human skeleton, there are three types which are fibrous joints, cartilaginous joints, and synovial joints.

1. **Fibrous joints:** At these joints; the bones are fused with fibrous tissues does not allow movements, and by growing older its fibrous tissue change into bone tissue, these joints connect the bones of skull together through its serrated tips.

2. **Cartilaginous joints:** They are joints connect between the ends of some adjacent bones and allow a very limited movement like the cartilages which found between the vertebra of the vertebral column. (Shape 8).

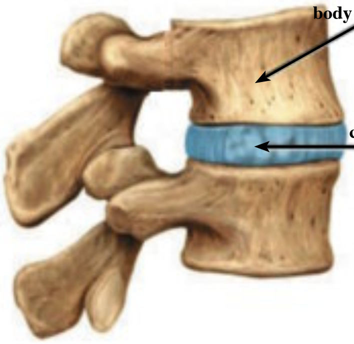


Fig. (8) Cartilaginous joints

3. **Synovial joints:** They represent most of the body joints, and the bones which in contact in the joints are covered with a delicate layer of transparent cartilaginous substance, and smooth which allow the movement of the bones easily with less friction. It is a flexible joints which bear shocks (trauma),and these joint contain a synovial fluid which facilitates the sliding of the cartilages that covering the bones.

From the examples of synovial joints:

- Elbow joint and Knee joint which considered a limited movement joints because it allow the movement of one bone in one direction only.
- Shoulder joint and Hip joint . They are wide movement joints which allow the movement of bones in many directions.

Fourthly Ligaments:

They are separated bundles of fibrous connective tissue, their tips are fixed on the two bones of the joint, and link the bones with each other at the joints and determine the movement of the joint in different directions, their fibers are characterized by a strong durability with the presence of a degree of elasticity to allow a little increase of their length in order not to be cut during the exposure of the external pressure.

But in some cases the ligament may be ruptured due to twisting of some joints as in the case of the cruciate ligament in the knee joint. (Fig. 9).

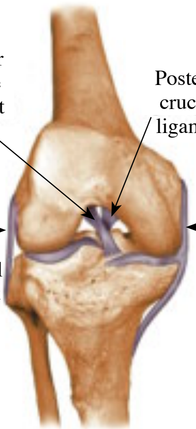


Fig. (9) Ligaments

Fifthly Tendons:

They are a strong connective tissue that link the muscles with bones at the joints which allow the movement of muscles during their contraction and relaxation. For example, Achilles tendon which connects the gastrocnemius muscle with heel bone. In some cases, this tendon may exposed to damage due to vigorous effort or sudden muscle contraction and the loss of elasticity in the muscles. From the symptoms of Achilles tendon tearing is inability of walking, heavy movement of foot, and acute pain, which can be treated with anti- inflammatory and analgesic drugs, using a medical splint, while the surgical intervention does not occurs except during the complete tearing of the lendon.

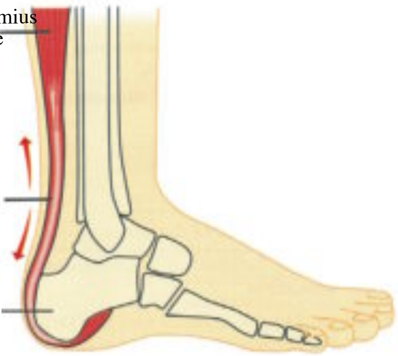


Fig. (10) Achilles tendon

Movement in living organisms

Movement : is a phenomenon which distinguishes living organisms.

The living organism has self-movement and can respond to external stimuli.

Movement in living organisms has many types. The continuous movement inside each cell for its vital activities such as cytoplasmic streaming, a positional movement of some organs such as peristalsis in vertebrate intestine . There a total movement by which the organism can move from place to place in search of food or for a mate or to avoid dangrous in its environment.

Movement of the animal from place to another leads to its spread in nature, as the means of movement was strong and fast the circle of its spread increase.

An animal cannot attain balance or move unless it possesses a solid support to which muscles are attached. Such kind of support may be external as in the arthropods or internal as in vertebrates. This is the skeleton.

The internal skeleton may be cartilaginous as in cartilaginous fish or bony as in bony fish. Whaterver the kind of skeleton, it consists of segments attached to each other by joints to facilitate movement.

First: Movement in Plants

As mentioned before, leaves of some plants are affected by touch which move as a respond to this stimuli. When the leaflets of Mimosa plant are touched, they collapse as if it went. This movement is known as movement by touch.

Also, the leaves of this plant and some leguminous plants partially close during darkness and return back to their original position in the light. Thus through the succession of light and dark movement of the leaves originate, which is similar to awakening and sleeping occurs and so this movement is known as sleeping movement. Plants characterized by tropism which is response of different parts of the plant to light, humidity and gravity .We can add to what you studied in sensation, the pulling movement and cytoplasmic movement, inside the cell.

Haptotropism: (pulling movement)

One special type of movement is pulling movement which is seen in tendrils of pea and also in roots of corms and bulbs. The tendril raises itself into the air and is likely to make contact with a solid object. It immediately twines closely around the object for a few turns in a spiral form. Its length decreases, and so the plant stem approaches the support, and grows vertically. Then the tendril becomes thickened and lays down a considerable amount of mechanical tissue, by formation of supporting tissue and become stronger.

Fig. (11) Movement in tendrils

If the tendril does not meet a support during its twining movement, it wilts and dies. The twining of the tendril around the support is due to slow growth on the side in contact with the support, and accelerated growth on the side of the tendril away from the support. This leads to elongation of the far side and so the tendril twines around the support (fig 11).

Corms and bulbs have pulling roots below them, by conrtaction of these roots, the corm or bulb is pulled downwards to a suitable level in the soil. Subterranean storing

stems remain at a suitable distance from the soil surface by the help of these pulling roots, which support the aerial parts against wind effects. (Fig 12).

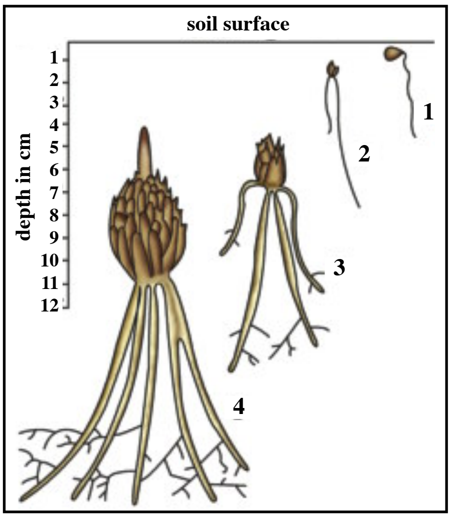


Fig. (12) Pull movement

Cytoplasmic streaming:

One of the main characteristics of the living cytoplasm is its continuous rotation inside the cell. This is shown when examining Elodea leaf cells (Fig. 13). It is in aquatic plant under the high power microscope. We can see the cytoplasm forming a thin layer lining the cell wall internally and streaming in a rotational movement in one direction. This movement is indicated by the movement of the chloroplasts embedded in the cytoplasm,

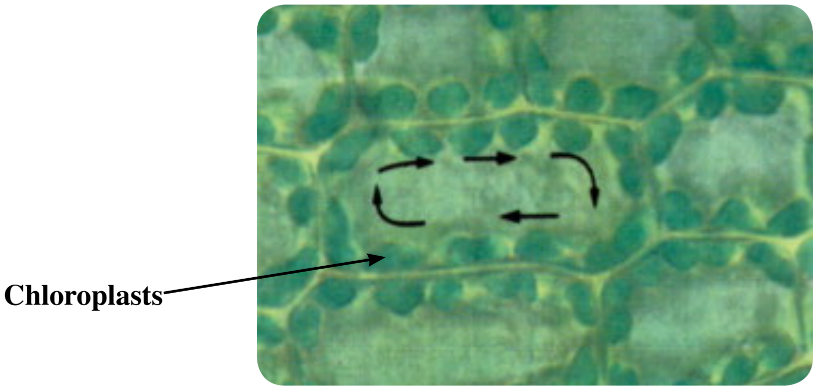


Fig. (13) Cytoplasmic streaming

Second: Movement in Man

The study is concrened with the movement in man as an example for mammals. Looking for your hands while turning over these pages, or your legs while walking on your way to school, you will find that the movement depends on three systems, skeletal system which supports the movement of limbs, the muscular system for contraction and relaxation of the muscles that move the limbs and the nervous system whichhhhh gives the order to the muscles to contract and relax.

The Muscular system:

The muscular system is a group of body muscles by which different parts of body can move.

The unit of structure of the muscular system is the muscle. The muscle consists of a muscular tissue. These muscles enable man to perform mechanical movements and transfer from one place to another and usually known as flesh. The number of muscles in man is about 620 muscles or more.

Functions of muscles:

The muscles are characterized generally by being filamentous and have the ability of contraction and relaxation.

Muscle contraction is important to perform the following functions:

a) Movement, and includes the change in the position of certain organ in relation to other parts of the body.

b) Transportation from one place to another.

c) Continuous movement of blood inside the blood vessels and to maintain normal blood pressure inside blood vessels through the contraction of the smooth muscles "involuntary" in the wall of blood vessels.

d) Maintain body posture either in sitting or standing postions especially by the muscles of neck, trunk and lower limbs.

Structure of the skeletal muscle:

The skeletal muscle consists of a large number of thin filaments called muscle cells or muscle fibres. Each muscle fibre consists of a group of myofibrils, 1000 to 2000 in number, arranged

longitudinally and parallel to the longitudinal axis of the muscle. Each muscle fibre contains a large number of nuclei (multinucleated).

Each muscle fibre consists of:

a) The protoplasm contain cytoplasm called sarcoplasm.

b) The membrane which surrounds the sarcoplasm is called sarcolemma.

c) The muscle fibres are collected in groups called muscle bundles surrounded by a membrane called perimysium.

d) Each muscle fibre consists of:

1. Group of discs the light band called I-band and bisected by a dark line called Z-line. It is formed of a thin protein filaments called actin.

2. Groups of discs the dark band is called A-band and bisected by a semi-light area called H-zone. It is formed of another thick protein filaments called myosin (Fig. 14).

3. The distance between each suecessive two Z-lines is called sarcomere.

   Note that, the dark and light bands present in the skeletal muscles and cardiac muscles and hence called striated muscles. This pattern is not present in the smooth muscles which are also called unstriated muscles.

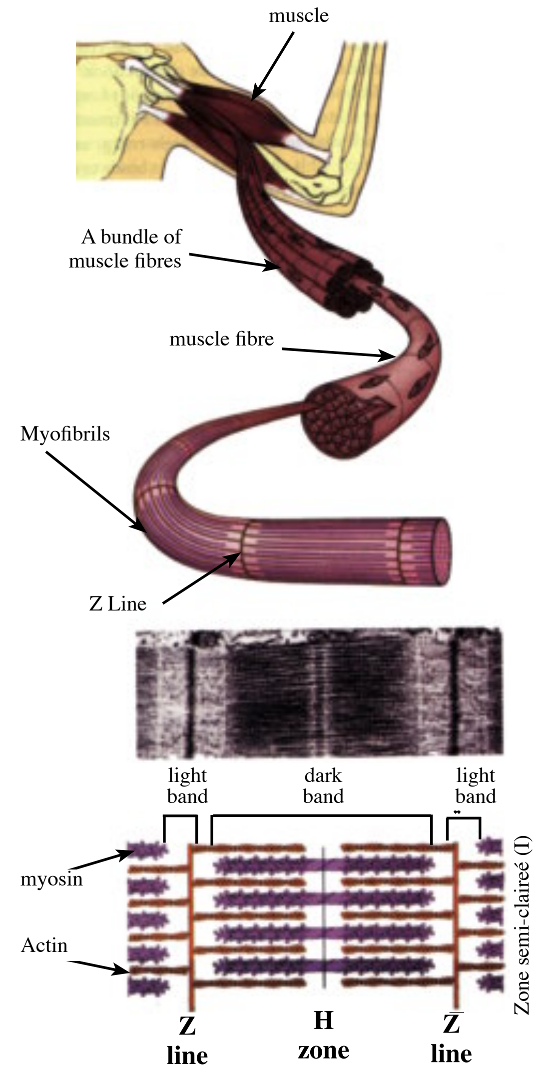


Fig. (14) The Skeletal Muscle

Muscle contraction:

The muscles have the a bility to contract and relax causing diffrent types of body movement.

Three main systems coordinate together to perform proper different body movements which are:

a) The skeletal (bony) system: as it provides a suitable site of connection of muscles from one side and to support the moving limbs from the other side, accordingly the joints play an important role in movment.

b) The nervous system: which gives the orders for muscles (in the from of nerve impulse) to contract and relax.

c) The muscular system: which is responsible for movement.

Most of the body muscles are under the control of will and called voluntary muscles (skeletal, striated muscles). Other muscles are not under the control of will and called involuntary muscles.

According to the previously mentioned information we have to answer the following questions:

a) How does the muscle contract?

b) What are the role of nerve impulse and the physiology of muscle response to nervous stimulation?

c) How all these parts coordinate together?

How the nerve impulse pass to the skeletal muscle:

1. In skeletal muscles, the outer surface of the muscle fibre membrane is (+ve) positively charged while the inner surface is (-ve) negatively charged, that form potential difference due to the difference of the ions concentrations between outside and inside the membrane.

2. The stimulus for muscle contraction is the motor impulses that coming from the brain and spinal cord through the motor nerve which is connected firmly with muscle fiber through synapse.

3. The synapse has synaptic vesicles contain neurochemical transmitters as acetylcholine.

4. When the motor impulses reach the synapse, the calcium pump in the cell membrane push the calcium ions inside the cell causing rupture of the synaptic vesicles to release the neurochemical transmitters as acetylcholine through the synaptic cleft between

the nerve fibre and the membrane of the muscle fibre change its permeability so, the sodium ions pass through the membrane causing depolarization (+ve inside and -ve outside) this leads to muscle contraction.

5. After a part of a second the potential difference of the muscle fibre membrane returns to its normal state “repolarization” due to the action of Cholinesterase enzyme, found in large amount at neuromuscular junctions which destroys acetylcholine into choline and cetic acid, so its acion. The membrane permeability to ions returns to the resting state it is now ready to be stimulated and respond again and so on.

Mechanism of Muscle contraction (The theory of sliding filaments)

The most acceptable theory for muscle contraction is the theory of Huxely. This theory depends on the microscopic sturcture of the muscle fibre which consists of myofibrils. Each myofibrils consists of thin actin filaments and thick myosin filaments as previously mentioned. After comparing a muscle fibre in a state of contraction with another fibre in a state of relaxation using electorn microscope.

Huxely concluded that the protein filaments slide over each other due to the presence of transverse links formed by the help of calcium ions extended from the myosin filaments and attach to the actin filaments.

The transverse links act as hooks that pull the actin filaments from both sides towards each other by using the energy stored in ATP leading to contraction of the muscle fiber.

During the contraction the (Z) lines become closed to each other, so the muscle contract, when the stimulus disappears, the transverse links move away from the actin filaments, then the muscle relax and the (Z) lines move away from each other, and the sarcomeres (the muscle peice) return to the fundamental length. Fig. (15).

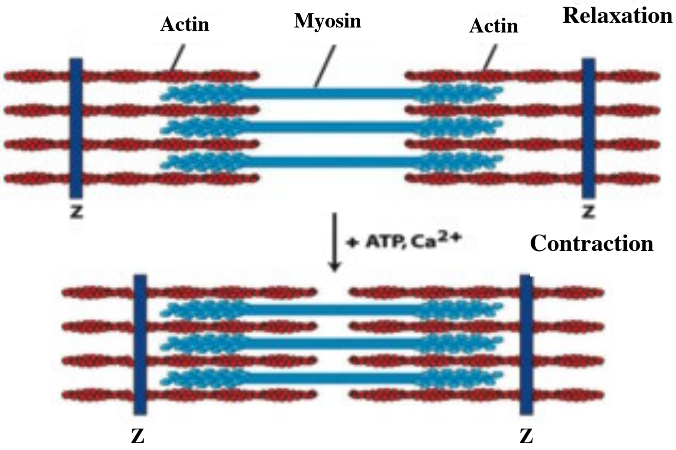


Fig. (15) The muscle contraction

The muscle consumes a part of the ATP stored energy to separate the transverse links from the actin filaments, so the deficiency of ATP may lead to prevent the separation between the transverse links and the actin filaments therefore the muscle still in a contraction state and can not relax.

This theory does not explain the contraction of unstriated smooth muscle although scientific reports suggest that the protein filaments in smooth muscle are almost similar to that in skeletal muscles.

The Motor Unit:

The motor unit is the unit of function of the skeletal muscle. The muscle contraction is the summation of all motor units forming the muscle.

Each motor unit consists of a group of muscle fibres and the nerve fibre supplying them. As the motor nerve fibre enters the muscle it divides into a large number of branches which supply a group of muscle fibres (5-100). Esch terminal branch attaches one muscle fibre at a place called the motor end plate and the point of connection is called the neuromuscular junction.

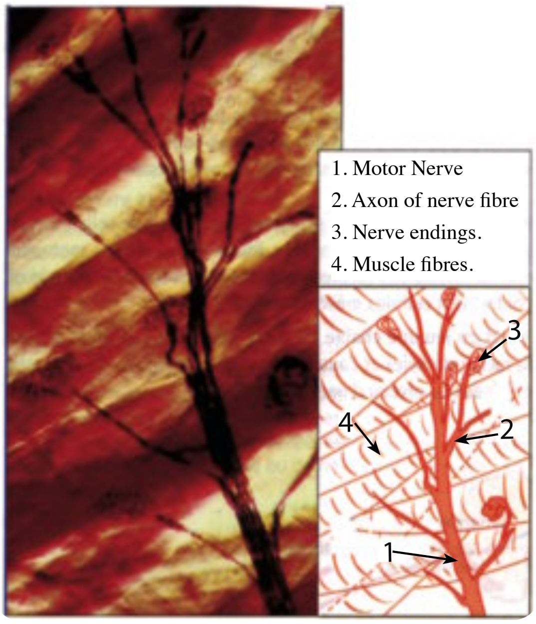


Fig. (16) The motor unit

Muscle fatigue:

- Repeated and rapid contraction of muscle leads to its fatigue due to the inability of the blood to supply the muscle rapidly with the oxygen needed for respiration and energy production.
- Accordingly the muscle converts glycogen (animal starch) to glucose which oxidized anaerobically (shortage of oxygen) to produce energy to allow the muscle to contract, causing the accumulation of lactic acid which causes muscle fatigue.

- The shortage of ATP in the muscle leads to prevent the separation of the transverse links from the actin filaments, so the muscle still in the case of contraction and can’t relax that causing painful muscle spasm.
- At rest the muscle supplied by enough amount of oxygen to perform aerobic cellular respiration, which produces a large amount of ATP causing that separate the transverse links from the actin filaments and the muscle go on alternation of contraction and relaxation.
- The excessive spasm may leads to tear the muscle causing bleeding, also the muscle spasm may be caused due to the troubles that resulted from the arrival of incorrect nerve impulses from the brain to the muscles during its normal performance.

Questions

1. Choose the correct answer :

1. The movement in man takes place by coordination of a group of systems which are:

a) The muscular, the skeletal and the circulatory systems.

b) The respiratory, the nervous and the skeletal systems.

c) The skeletal, the nervous and the muscular systems.

d) The skeletal, the respiratory and the circulatory systems.

2. The direct energy store for the muscle is:

a) ATP molecules.

b) Glycogen.

c) Glucose.

d) Lactic acid.

3. Muscle spasm during fatigue is due to accumulation of a chemical substance called:

a) Carbon dioxide.

b) Alcohol.

c) Lactic acid.

d) Amino acid.

4. Physiological support in plants is represented by:

a) Thickness of plant cell to prevent water loss in plants.

b) Turgidity of plant cell.

c) Turgidity of vessels filled with nutrients.

d) Deposition of cellulose on cell walls.

2. Give reason :

1. Tendrils twin around the support.
2. Presence of girdles in the appendicular skeleton of animals.
3. Muscle fatigue.
4. Blood is in continuons movement inside the blood vessel.
5. The sliding theory of muscle contraction is the most acceptable to explain muscle contraction.
6. Presence of the enzyme cholinesterase at the neuromuscular junction.

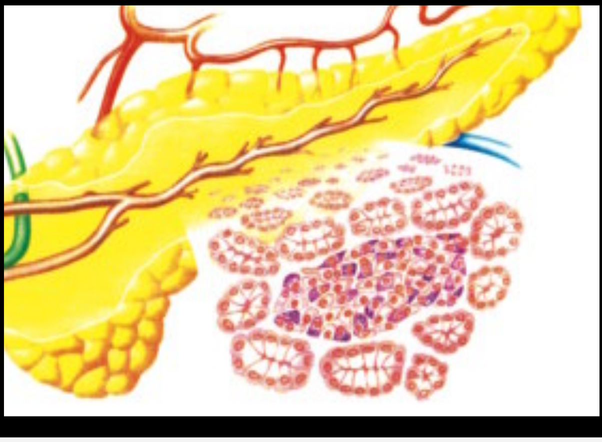
3. Draw a labelled diagram of vertebra.

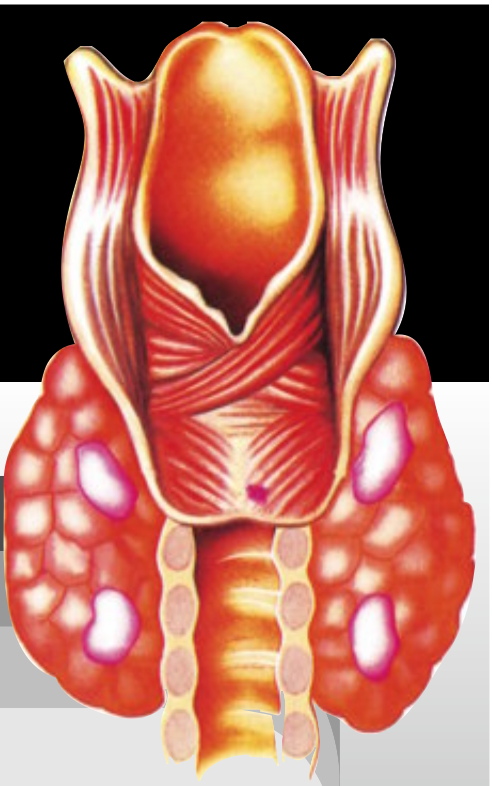
4. What do you know about:

Coccigeal region - pelvic girdle - pectoral girdle - scapula - muscle bundle - cruciate ligament - Achilles tendon - synovial Joints.

5. The motor unit is the junctional unit of skeletal muscle. Discuss with reference to its componants.

6. The movement is a result of coordination of the skeletal, the muscular and the nervous system in man. Explain.





Chapter Two

Hormonal Coordination in Living Organisms

At the end of this chapter the student should be able to :

- Determine the scientific efforts to discover hormones.
- Determine the importance of auxins in plants.
- Determine the function of hormones.
- Mention the endocrine glands in man.
- Determine the characters of hormones.
- Compare between exocrine and endocrine glands in man.
- Determine the role of pitutary gland as a master gland.
- Determine the role of some glands as thyroid, parathyroid and adrenal glands.
- Determine the role of pancreas in regulating the sugar content in blood.
- Know the effect of hypo and hyper secretion of hormones.
- Compare between hormonal and neural coordination.

The Endocrine System

As mentioned before, all body functions are under nervous and hormonal control. The endocrine glands are ductless glands and secret hormones directly to the blood stream. Any increase or decrease in the amount of secretion of any hormone leads to disturbances in the functions and results in pathological changes and symptoms characteristic for this hormone.

Hormones

The hormone is defined as a chemical substance synthesized and secreted by an endocrine gland and transported by the blood to another organ where it affects the function and the growth of this organ. Most of the effects of hormones are in the form of stimulation of other gland or organs.

Discovery of Animal Hormones:

1. Cloud Bernar:

He studied the liver functions in 1855 and considered the stored sugar in the liver as an internal secretion and the bile as an external secretion.

2. Starling in 1905, found that:

a) The pancreas starts to secret the pancreatic juice directly after the arrival of food to the duodenum even after the nerve supply was cut.

b) He concluded that there must be a non nervous stimulation.

c) Finally, he discovered the presence of certain chemical substances secreted from the mucus membrane lining the duodenum which pass to the blood to stimulate the pancreas to secret the pancreatic juice.

d) He named these substances hormones (A Greek word which means activators).

Hormones in plants

B. Jensen in 1913 was able to explain phototropism of a growing point in view of auxins (plant hormones). He proved that the connection between the receptor and the

region of curvature occurs due to the auxins as indole acetic acid. Plants have no special glands to secrete hormones (auxins) but they are secreted by the tip of the coleoplite and buds and affect other parts of the plant.

The importance of auxins:

1. Regulate plant growth.
2. Organizing the development of tissues.
3. The formation of flowers, leaf fall, fruit formation and ripening.
4. Affects the function of all tissues.

Hormonal Coordination in Man

The scientists were able to know the functions of hormones through:

1. The study of symptoms resulted from enlargement or removal of one of the endocrine glands (in man and animals).
2. The study of the chemical structure of extracts of endocrine glands and their effects on different vital activities.

Characteristics of Hormones:

1. Hormones are organic substances. Some hormones are proteins, others are amino acids or steroids (lipid derivatives).
2. Hormones are secreted in very small amounts in micrograms (1/1000 milligram).
3. Hormones perform the following important functions:
   a) Keep the balance of the internal environment of the body (homeostasis).
   b) Body growth.
   c) Sexual maturity.
   d) Metabolism (utilization of food).
   e) Behaviour and emotional and intellectual development.

Glands in Man

Three types of glands are present in man:

1. Exocrine glands:

Each exocrine gland consists of a secretory part in addition to a duct or a system of ducts which carries the secretions either to a cavity inside the body, as salivary and digestive glands, or to outside the body, as the sweat glands.

2. Endocrine glands:

They are ductless glands, that secret hormones directly to blood.

3. Mixed gland :

It consists of an exocrine and an endocrine parts such as pancreas.

The human body contains many endocrine glands (Fig. 1) each of which secrets one or two groups of hormones.

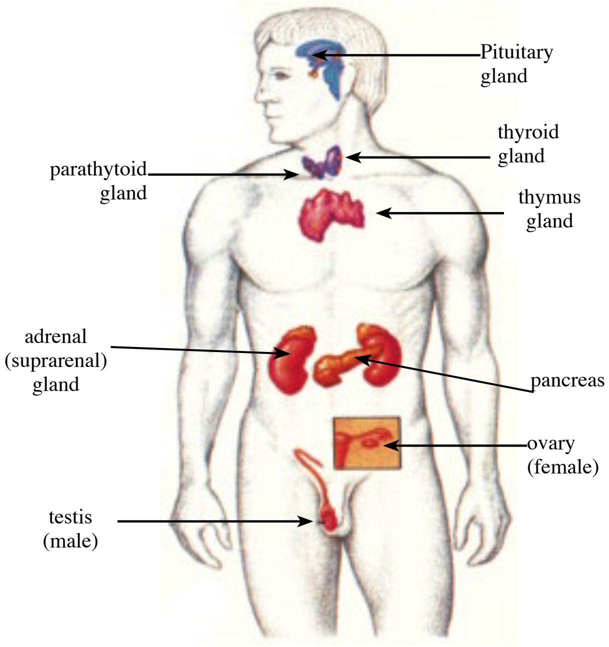


Fig. (1)
Distribution of endocrine glands in the human body

First : Pituitary gland :

It is considered as the master gland as it controls the functions and secretion of most of the endocrine glands. The gland is located beneath the brain and in connection with the hypothalamus. The gland consists of two parts:

A) Adenohypophysis:

It consists of the anterior and middle lobe.

B) Neurohypophysis:

It consists of the posterior lobe and a part of the brain called the infundibulum (a stalk connecting the gland to the brain).

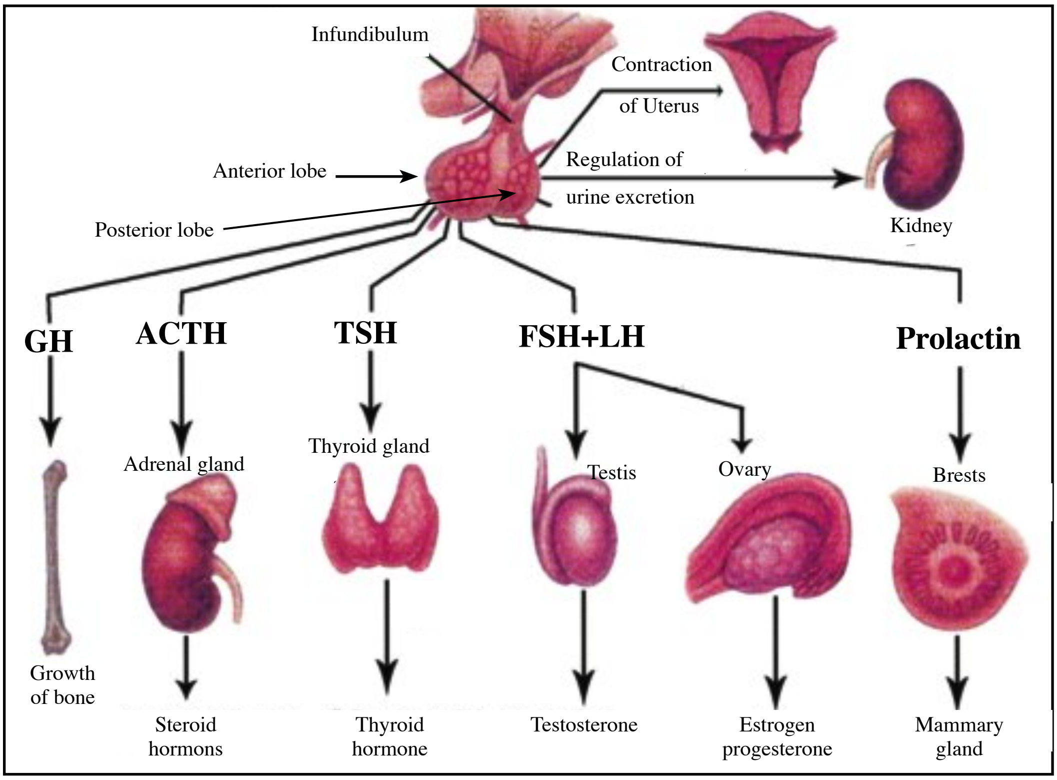


Fig. (2) : Pituitary gland and its hormones

Hormones of the Adenohypophysis (anterior lobe):

1. Growth hormone (G.H.)

It controls metabolism especially protein synthesis, accordingly it controls the physical growth of the body.

Hyposecretion of this hormone during childhood causes Dwarfism and its hypersecretion during the same period causes Gigantism.

Hypersecretion of G.H. in adults causes Acromegaly which is characterized by increased bone growth at the extremities and characterized by enlarged hands, feet, fingers and bones of the face.

2. Pituitary Trophins

A group of hormones that affect the activity and secretion of other glands and includes:

a) Thyrotrophin (thyroid stimulating hormones) (T.S.H.).

b) Adrenocorticotrophic hormone (A.C.T.H.) which affects the function of the adrenal (Suprarenal) cortex.

c) Gonadotrophic hormones - Affect the function of gonads (ovaries in females and testes in males).

This group includes

1. Follicle stimulating hormone (F.S.H) which affects the growth of the ovarian follicles and formation of Graafian follicles in females and formation of seminiferous tubules, and spermatozoa in testis of males.

2. Lutinizing hormone (L.H.) which stimulates the formation of corpus luteum in females and the formation and secretion of interstitial cells in the testes of males.

   These two hormones are important for complete the sexual maturity of individual.

3. Prolactin : stimulates milk secretion from mammary glands.

Hormones of the neurohypophysis

Hormones of this part are secreted from the nerve secreting cells in the hypothalamus and reach the neurohypophysis (posterior lobe of pituitary) and include the following hormones:

1. Antidiuretic hormone (A.D.H) (Vasopression)

This hormone increases the reabsorption of water in the nephrons and decreasing the volume of urine excreted. In addition it increases blood pressure.

2. Oxytocin

This hormone affects the uterine contraction and increases it during delivery (labour). Gynacologests use this hormone to accelerate the birth of a baby by stimulating strong contractions of uterine muscles. In addition oxytocin stimulates the release of milk from mammary glands as a response of lactation.

Second : The Thyroid Gland

The gland lies in the neck infront of and in close contact with the trachea.

The colour is slightly red. The gland consists of two lobes connected together by an isthmus. It is surrounded by connective tissue.

Functions:

The gland secretes the hormone thyroxin. Iodine is essential for the formation of this hormone. Thyroxin has many effects on different parts of the body as for example:

a) It affects and stimulates physical and mental growth and development.

b) It affects the basal metabolic rate.

c) It increases the absorption of monosaccharides from the intestine.

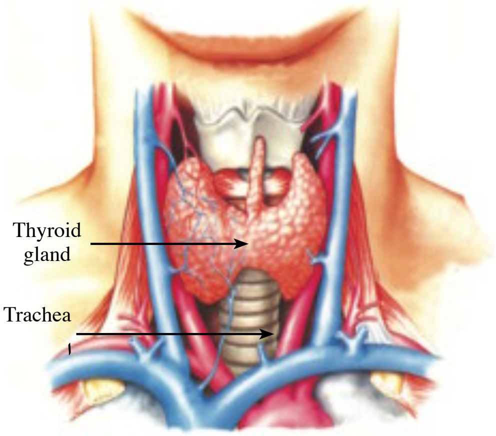


Fig. (3) Thyroid gland

d) It maintains healthy skin and hair.

The gland secretes another hormone called calcitonin which decreases the calcium level in the blood and prevents its withdraw from the bones.

The diseases of thyroid Gland

The diseases are caused by increases or decreases the secretion of thyroxin hormone.

1. Hypothyroidism:

leads to enlargement of thyroid gland which called simple goiter

Simple goiter:

It occurs as a result of decrease of thyroxine hormone due to iodine deficiency in food, water and air. The treatment involves administration of iodine supplement in salt and different food.

If this case is not treated this will lead to complications as :

a- cretinism:

Cretinism due to a cute decreasing of thyroid secretion in childhood leading to occurrence of complications as it leads to a condition called cretinism characterized by a retardation in physical and mental growth associated with large head, short stature, short neck, permanent mental retardation and a delay in sexual maturity.

b- myxodema:

Occurs due to acute decrease of thyroxine secretion in adult and characterized by dry skin, loss of hair, decreased mental and physical activity, weight gain and obesity, decreased in basic metabolic rate, intolerance to cold, decreased heart beats and rapid fatigability. The treatment is by regular consultation of a specialist and by administration of thyroxin or gland extracts.

2- Hyperthyroidism

Leads to the enlargement of the thyroid gland associated called exophthalmic goiter.

Exophthalmic goiter:

Resulted from the increase of thyroxine secretion which causes noticed enlargement of the thyroid gland and enlargement of the anterior part of the neck with protrusion of the eye balls. Hypersecretion of thyroxin leads to increase in food oxidation and metabolic rate, loss of weight, increase in heart beats and nervous irritability. The treatment of this case is by either surgical removal of a part of the gland or by the use of other medications to suppress the gland.

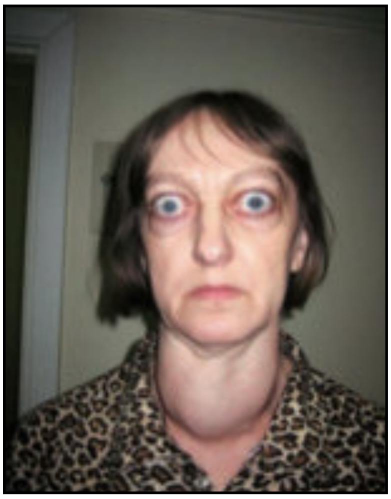


Fig. (4) Exophthalmic goiter

Third : Parathyroid glands:

This gland consists of four small separate lobes, two on each side of the thyroid gland. The gland secrets a hormone called parathormone. The hormone is secreted when the calcium level in the blood is below normal.

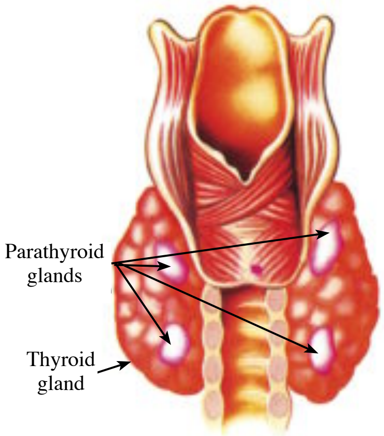


Fig. (5) Parathyroid glands

Parathormone plays an important role in preserving the calcium level in the blood to normal Hypersecretion of parathormone (hyperparathyroidism) leads to:

a) Increase in the calcium level in blood.

b) As most of the calcium is released from bone, the condition is associated with increased bone resorption and the bones become fragile and liable for bending and fracture.

Hyposecretion of parathormone (hypoparathyroidism) leads to :

a) Painful convulsions and muscle spasms (as a result of decreased calcium in blood).

b) Increased excitability of nervous system.

Fourth : The adrenal "suprarenal" glands

They are two glands each located above one of the two kidneys. Each gland consists anatomically and physiologically of two regions, an outer cortex and an inner medulla.

1- Hormones of the Cortex:

The cortex of adrenal gland secretes many hormones as the group of steroid which can be classified into Three groups of hormones

a. Glucocorticoids:

They include cortison and corticosterone. The main function of them is to regulate carbohydrate "sugars - starch" metabolism in the body.

b. Mineralocorticoids:

Aldosteronl is one of this group which plays an important role in minerals balance in the body. This hormone increases reabsorption of sodium and increases the excretion of exces potassium by the kidney.

c. Sex hormones:

Although the main source of sex hormones are the testes in male and the ovaries in females, similar hormones are also secreted from the adrenal cortex, as male sex hormone testosterone and the female sex hormones estrogen and progesteron.

Tumorous or any condition leads to the unbalance secretion of adrenal cortex and results in the increase in the level of sex hormone above normal. It leads to musculanization in female, femineization in male and atrophy of gonads in both sexes.

2- Hormones of the medulla:

It secrets the two hormones adrenaline and noradrenaline which are responsible for the vital activities occurring in the body when the individual is subjected to emergency situations as in fear, fight and excitation and during muscular exercise. These two hormones increase the sugar (glucose) level in the blood by increasing the breakdown of the glycogen stores of liver into glucose, increase the speed and force of contraction of the heart and increases blood pressure. All these changes enable the muscles to take their demands of energy needed for contraction and increase in the rate of oxygen consumption.

Fifth : The Pancreas:

It is a mixed gland with exocrine and endocrine secretions. The exocrine secretion is in the form of pancreatic juice secreted from pancreatic acini through pancreatic duct into duodenum and also it can secrete hormones directly to blood from groups of cells called islets of langerhans which contain tow types of cells.

a) Alpha cells : They are small in number and secrete a hormone called glucagon.

b) Beta cells: They represent the majority of cells and secret a hormone called insulin.

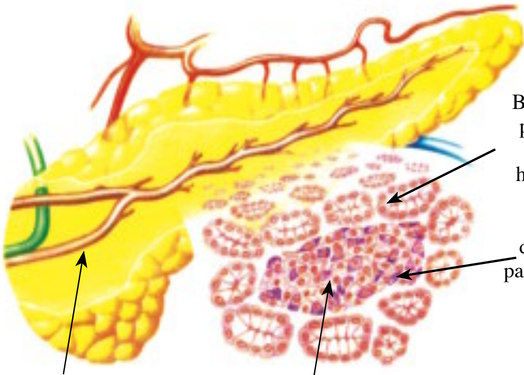


Fig. (6) Pancreas and islets of langerhans

The two hormones are responsible for the regulation of glucose level in the blood and keep it constant at level ranging from 80 - 120 mg/ 100 cm^3 blood.

Functions of insulin hormone

The insulin decreases the glucose level in the blood through:

a) It stimulates the oxidation and utilization of glucose by the cells and different body tissues as it is important for transport of all monosaccharides (except fructose) across the cell membrane to inside it to be utilized .

b) Controls the relation between stored glycogen and blood glucose .

It stimulates the conversion of glucose to glycogen or to lipids to be stored in the liver and muscles or other body tissues.

Decrease in the secretion of insulin leads to a disease called Diabetes Mellitus,

characterized by disturbance in the metabolism of carbohydrates (glucose) and lipids.

The patient with Diabetes Mellitus complains of increase glucose level in the blood associated with the abnormal appearance and excretion of glucose in urine with the excretion of a large volume of water which explains the symptoms of continuous thirst sensation and excessive micturition.

Functions of Glucagon hormone:

It antagonizes the action of insulin, where it increases the glucose level in the blood through the conversion of glycogen to glucose (only in liver).

Sixth: The sex glands (The gonads):

In addition to the main function of gonads (ovaries and testes) in production of gametes (ovaries and testes) in production of gametes (ova and spermatozoa), they produce and secret a group of sex hormones responsible for growth of genital organs and the appearance of secondary sexual characters. Sex hormones are steroids.

1. Male sex hormones :

They are called Androgens and secreted by the interstitial cells of testes. Male sex hormones are Testosterone and androsterone. They are responsible for the growth of the prostate gland, seminal vesicles and the appearance of male secondary sexual characters.

2. Female sex hormones:

known as oestrogens and secreted from the ovary:

a) Oestrogen hormone (oestradiol): It is secreted from the graafian follicle of ovary.

It helps the appearance of female secondary sexual characters such as the increase in the size of the breasts and regulates the menstural cycle.

b) Progesteron hormone: It is secreted from the corpus luteum of the ovary and placenta and it is important during pregnancy as it regulates the vascularity of the uterine wall and prepares it to receive the embryo. In addition, progesterone is responsible for the changes taking place in mammary glands during pregnancy.

c) **Relaxin hormone:** It is secreted from the placenta and uterus. It causes relaxation of pubis symphesis at the end of pregnancy to facilitate the process of delivery.

Seventh: The gastrointestinal Hormones:

In addition to the exocrine function of the mucous membrane lining the alimentary canal, it secrets also a group of hormones which regulate and stimulate the different parts of alimentary canal to secret the digestive juices. Examples of these hormones are:

- Gastrin hormone secreted from the stomach wall and transferred through the blood to activate the stomach again to secrete gastric juice.

- Secretin and Cholecystokinin which are secreted from the intestinal wall and transferred through the blood to the pancreas to stimulate it secret pancreatic juice.

Questions

1. Give reasons :

- Gigantism in children.
- The pituitary gland is the master gland.
- Milk secretion from mammary gland of a lactating female.
- Uterine contractions during delivery.
- Some individuals have exophathalamic goiter.
- Increased secretion of parathyroid hormones leads to fragile bones liable to fracture.
- Muscularization of female.
- Adrenaline secretion prepares the body for emergency situation, excitation and anger.
- Pancreas is a mixed gland.
- The sense of thirst in diabetic patients.
- Some diabetic patients may go into coma.
- Nervous regulation is faster than hormonal regulation.
- Extract of posterior lobe of pituitary gland of cows during some cases of delivery.

2. Choose the correct answer :

1. The gland which stimulates the mammary gland to secret milk after delivery is:

a) Ovary. b) Adrenal.

c) Parathyroid. d) Pituitary.

2. The adrenaline:

a) Stimulates the body to perform activities needed during emergency.

b) Stimulates the liver to convert glucose to glycogen.

c) Is responsible for the appearance of secondary sexual characters.

d) Increases the resistance of body to infection and microbe.

3. Exophthalmic goiter is due to the increase in the hormone:

a) Thyroxin. b) Growth hormone.

c) Cortisone. d) Parathormone.

3. What is the role of each of the following scientists in the discovery of hormones.

Cloud - Starling Bernard

4. Enlargement of the thyroid gland leads to pathological features which differ according to the type of activity of the gland during this enlargement. Discuss this statement with reference to:

a) The site of thyroid gland in human body.

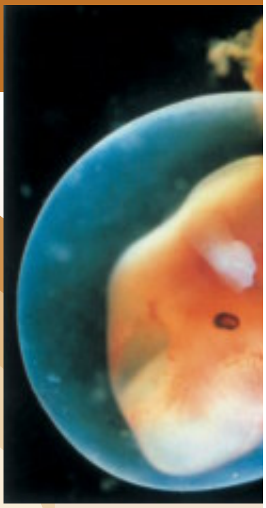
b) The function of the thyroid gland.

c) Effect of hyper and hyposecretion of the gland on the body.

5. What are the characteristics of hormones?

6. The pituitary gland consists of adenohypophysis and neurohypophysis. What are the hormones of each part and their importance for man?

7. Compare between Insulin and Glucagon.

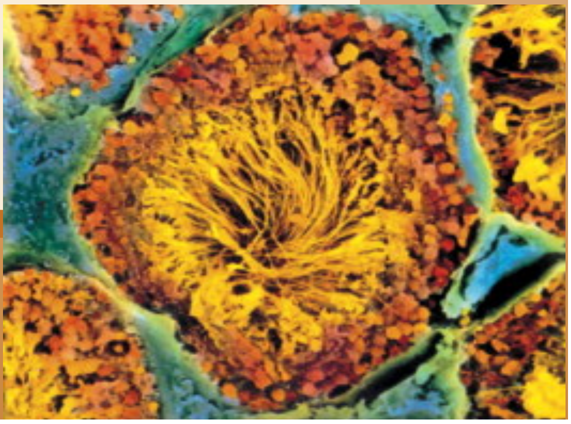


Chapter Three

Reproduction in the Living Organism

At the end of this chapter the student should be able to :

- Recognize the concept of reproduction and its importance.
- Discover the capacities of reproduction among organisms.
- Recognize the asexual and sexual reproduction among organisms.
- Recognize the life cycle of plasmodium which causes the malaria disease.
- Compare between asexual and sexual reproduction.
- Recognize how the seeds and fruits are formed.
- Recognize the male and female genital systems in human beings.
- Recognize the stages of the spermatogenesis and oogenesis in human.
- Recognize the menstrual cycle in woman and the role of hormone regulation.
- Recognize how the embryo survives inside the uterus and the stages of its formation and development.
- Discover how the twins phenomenon occurs and its types.
- Recognize the means of contraceptive.
- Compare between the embryonic culture and renucleation.
- Recognize the method of extra - uterine fertilization (test tube baby).
- Appreciate the efforts of scientists in the technological progress of the reproduction process.
- Appreciate the capability of the Great Creator in reproduction of generations to continue life on Earth.



All living organisms depend on various sources for supplying them with energy that is necessary for their life. However, they stay living on this Earth for a limited period which eventually ends by death. So they should perform the functions of nutrition, respiration, excretion and sensation in order to succeed in staying alive even shortly on Earth. What about the function of reproduction?

Importance of reproduction to organisms

Any non breeding organism can maintain life naturally. Moreover, the removal of genital organs from some organisms did not affect their normal life. Hence the reproductive function is less important to the individual's life than the above mentioned functions. If any of these functions was impeded, the individual perishes immediately. Accordingly, reproduction depends on all the other functions and not the reverse. However, it is the function that assures the continuity of species on Earth after death of individuals. If it is impeded at the population level, extinction of the species occurs.

All the organisms start live acting to secure their existence as individuals. They save the necessary energy for growth up to certain stage. The they begin acting for maintenance of species through reproduction, to which most of their energy and behaviour become directed.

The reproductive capacities among organisms

The reproductive capacities differ among organisms due to the various ambient, prevalent hard ships, life nature, their duration ages and their sizes... etc.

- So aquatic organisms produce much more progeny than their land relatives.
- Also parasits produce much more progeny than organisms in order to compensate their loss.
- Similarly, the production of primitive or short - aged organisms progeny is much more than higher or long - aged ones since the production of the latter is less endangered, due to the provided care and protection.

Consequently, the species and individuals seen around at present, express the success of their ancestors in reproduction and in overcoming the hardships they faced throughout their consecutive generations. Conversely, many of the extinct forms had failed to continue uptill now, from these we recall the Dinosaurs and other giant reptiles that did not continue in reproduction, and so became in the record of geological history. Similar fossil forms are known in the animal and plant kingdoms.

Methods of reproduction in living organisms

Living organisms reproduce by many ways and modes in order for their species to continue.

These modes can be grouped into 2 main methods:

First: Asexual Reproduction

This comprises a mere isolation of a body part either a spore cell or many cells or tissues and their growth into a new organism that fully resembles the original from which the above part has been isolated. So the features of the following generations remain the same, even if the surrounding conditions change.

At any change in the environment, most of the offsprings become exposed to destruction unless their parents had been adapted for that change. This kind of reproduction is common in the plant kingdom but is limited to some primitive forms of the animal kingdom.

- This reproduction depends on mitotic division of cells, where cells resulting from this division receive a complete copy (2N) of original chromosomes.

Types of asexual reproduction

Asexual reproduction in living organisms is taken place in various types. The most important are the following:

1. Binary Fission:

In which the nucleus divides by mitosis, then the cell that represents a unicellular organism divides into 2 cells, each become a new individual. Many protozoa such as Amoeba (Fig. 1) and Paramecium as well as simple Algae and Bacteria reproduce by this type under suitable conditions.

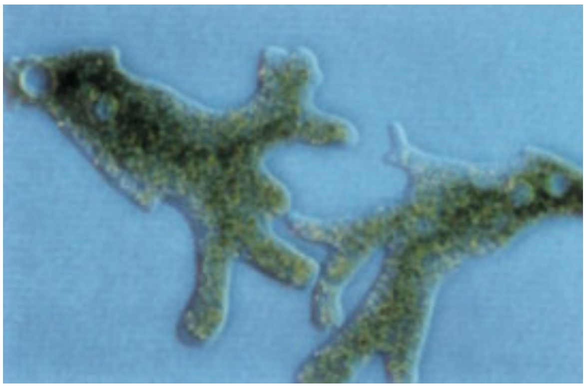


Fig. (1) Binary fission in Amoeba

On advent of unsuitable conditions, Amoeba secretes a chitinous coat around its body for protection. However, it usually divides within that coat several times by repeated binary fission. This leads to numerous young Amoebae that liberate from the cyst upon improvement of the surrounding conditions.

2. Budding

Some unicellular organisms as well as some multicellular ones reproduce by budding. In unicellular organisms as yeast fungus, the bud arises as a lateral projection from the original cell while the nucleus divides, mitotically into 2 nuclei. One of them remains in the mother cell while, the other moves towards the bud. It grows gradually and may remains connected with the mother cell till its full growth. Then it separates or continues in connection with the mother cell forming cellular colonies with other growing buds (Fig. 2).

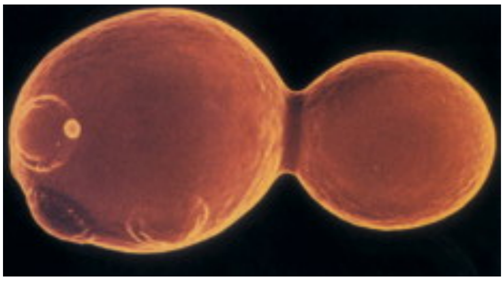


Fig. (2) Budding in Yeast

In multicellular forms such as sponges and Hydra, the bud grows as a cellular protrusion from one side of the body due to division of interstitial cells and their differentiation to a bud. This grows gradually to resemble the mother entirely (Fig. 3). It usually separates to start its independent live. It is to be mentioned that sponges and Hydra reproduce also sexually besides their capacity for regeneration.

Fig. (3) Budding in Hydra

3. Regeneration

This method is common in many plants and some animals such as Sponges and Hydra as well as some Worms and Sea Star (starfish). They are able to regenerate the lost parts of their bodies due to an accident or rupture. If the body of some animals is cut into several parts, each part can grow to a new individual. However, the capacity

for regeneration decreases in higher animals. In some crustaceans and amphibians it is limited to restoration of the cut parts only. In higher vertebrates regeneration never exceeds healing of wounds especially those located in skin, blood vessels and muscles.

Of the most exciting phenomenon, is the ability of Planaria (a common fresh water flat worm) to regenerate even if cut into several transverse pieces or 2 longitudinal parts. Each will grow into a new individual (Fig. 4).

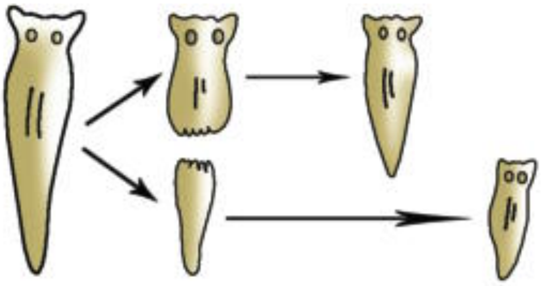


Fig. (4) Regeneration in Planaria

Similarly, the Hydra is able to regenerate if it is cut into several transverse pieces. Each part will grow into a new individual.

Also, the Sea Star (Fig. 5) feeds on the pearl mussels. (since it can devour about 10 of these mussels daily including the pearl).

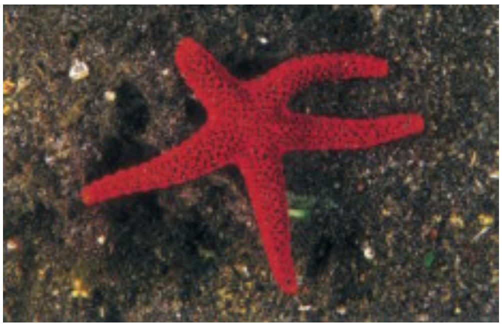


Fig. (5) The star fish

Therefore, breeders of those mussels in pearl farms were collecting sea stars, tearing them up to pieces and then throw them back into the sea.

Though they tried to get rid of them they were unintentionally helping their reproduction.

One of the star's arms with a piece of its central disc can regenerate to a full star within a short time.

4. Sporogony

Some primitive plants reproduce by means of single cells called spores that are adapted for direct growth into complete plants. A spore is formed of a cytoplasm with

little amount of water, a nucleus and a thick coat. When the spore matures, it liberates from the mother plant to be disseminated into air. Upon reaching to a suitable medium for growth, its coat ruptures while it absorbs water and divides several times by mitosis and grows to a new individual. Many fungi such as Bread mould (Fig. 6), Mushroom (Fig. 7) and some Algae and Ferns reproduce by sporogony.

Reproduction by spores has several advantages such as quick propagation, tolerance to hard conaitions and aistribution to distailt regions.

Fig. (6) Reproduction by sporogony in mushroom

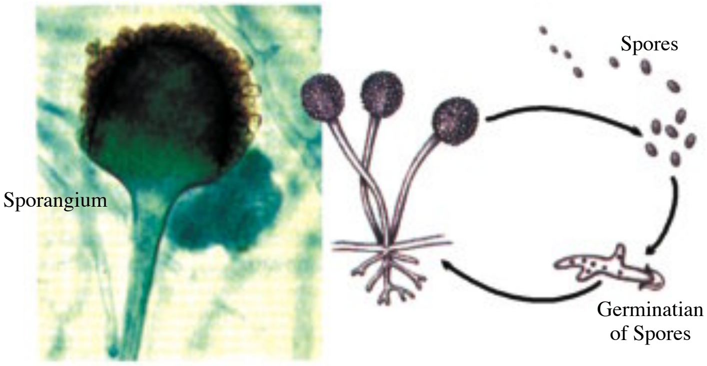


Fig. (7)
Reproduction by sporogony in Bread Mould

5. Parthenogenesis

This is the ability of the egg to develop to a new individual without being fertilized by a male gamete. It can be considered a special kind of asexual reproduction since, the progeny comes only from the mother.

Parthenogenesis occurs in a number of worms, crustaceans and insects. Honey bee is a known example, where the queen produces some eggs that develop without fertilization forming drones and some others that develop after fertilization to queen and workers, according to the type of food provided later on, Drones are haploid (N), the queen and workers are diploid (2N). In some other cases, the eggs may also result from a mitotic division where it develops to a diploid (2N) individuals from the beginning as was found in the aphid insect.

Parthenogenesis has been induced artificially by egg activation (e.g frog and sea

star) through its exposure to heat or electric shock irradiation, some salts agitation or pricking with a needle. These stimuli lead to duplication of their chromosomes and so develop without fertilization to individuals that are totally identical with the mother. By similar stimuli, early embryonic stages of rabbits were obtained from their eggs.

6. Tissue culture

Scientists carry out experiments of tissue culture on plants and animals. They grow their tissues in a seminatural nutrient medium and follow their differentiation and progress till a full organism is obtained. In an exciting experiment, a scientist separated small pieces of carro plant into conical flasks containing coconut milk, which comprises the whole plant hormones and nutrient elements. They began to grow and develop into a full carrot plant (Fig. 8).

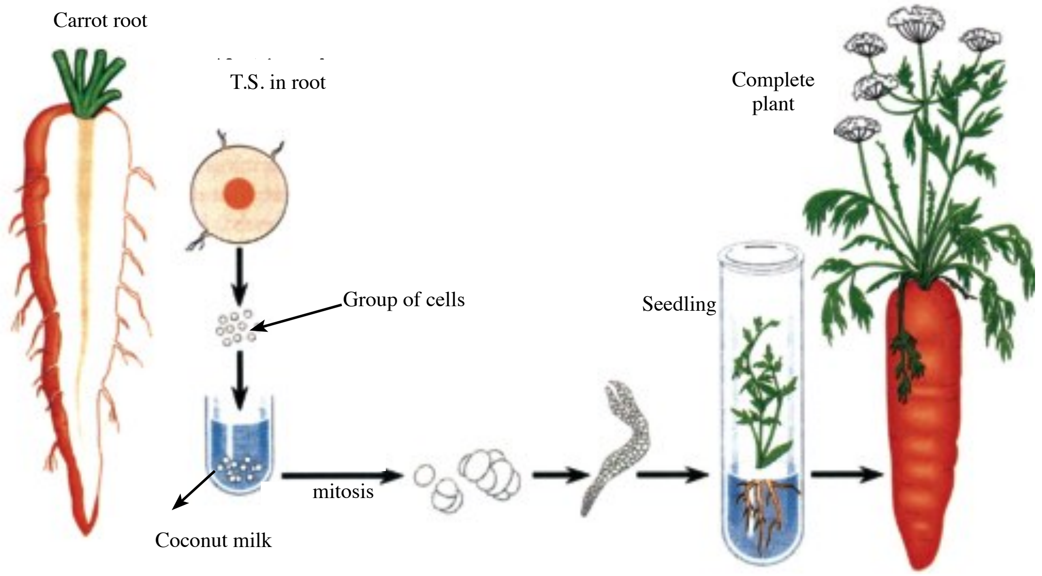


Fig. (8) Tissue culture in carrot plant

Later, he separated some cells from the same plant and cultivated them by the same method and obtained a whole plant.

Similarly, a tobacco plant was obtained from isolated cells of tobacco leaves that has been treated by the same method.

These experiments confirmed that any somatic cell in the plant comprises the whole genetic information.

The latter can be translated to a whole developed organism if cultivated in a proper nutrient medium containing plant hormoneswith certain ratio.

These methods are now applied in propagating rare plants or of desirable strains or of more resistance to diseases. Selected tissues for such culture can be preserved in liquid nitrogen for a long period while remaining alive till cultivation. Hence scientists foresee hopes on the progress of these techniques nearly in order to solve food problems and to shorten the time needed for growing desirable crops.

Second : Sexual Reproduction:

Sexual Reproduction necessitates the presence of two individuals, male and female for the production of sexual gametes. Gametes should meet for fusion during fertilization. At mating a male gamete meets with the proper female gamete and fuse to form the zygote. Zygote then divides and grows to the embryo then to the young and the adult that combines parents features. So the young receives from both parents even a minute part of their nuclear substance and thus becomes a blend from both. Conversely, the young in asexual reproduction receives nuclear substance from only one parent and so becomes a copy from it.

However sexual reproduction, needs more time and energy-consuming than asexual reproduction, since it occurs after elapse of certain age and preparation. In some cases, the parents should prepare the proper nest or burrow before mating. They may alternate in guarding the eggs and protection of the youngs till they grow larger. Some forms even face more hardships in order to protect their young, as they keep their embryos within their bodies till birth. These youngs may remain with their parents in a social life for more protection and learning more about their behaviour. Besides, production of new individuals is limited here to half of number of organisms i.e. females only but not the males. In asexual reproduction, all the individuals multiply. In spite of all the previous, sexual reproduction provides the descendants with continuous innovations in their genetic content that enable them to continue in the face of environmental variation.

The sexual reproduction depends on meiotic division, when forming gametes, the number of chromosomes is reduced to its half so, cells resulting from this division are haploid cells (N). During fertilization the male gamete fuses with the female gamete so the original number of chromosomes becomes (2N), which differs according to the kind of living organism.

Types of Sexual Reproduction

Sexual reproduction occurs by 2 main methods:

1. Conjugation

In primitive organisms such as some Protozoa, Algae and Fungi, reproduction occurs by mitosis at suitable conditions, but they turn to sexual reproduction by conjugation if subjected to drought or a change in water temperature or purity.

Conjugation in Spirogyra

Spirogyra is common in the green scum of standing water where its filaments float, each filament is formed of one row of cells. This fungus turns to conjugation on advent of unsuitable conditions. They are two types:

a) Scalariform conjugation:

- When two filaments contact each other, a protrusion grows inwards between opposite pairs of cells, then walls in-between disappear forming a conjugation tube.
- The protoplasm of each cell of one filament rolls up into a sphere and moves across the above tube to cell of the opposite filament forming a zygote. (Fig. 9).

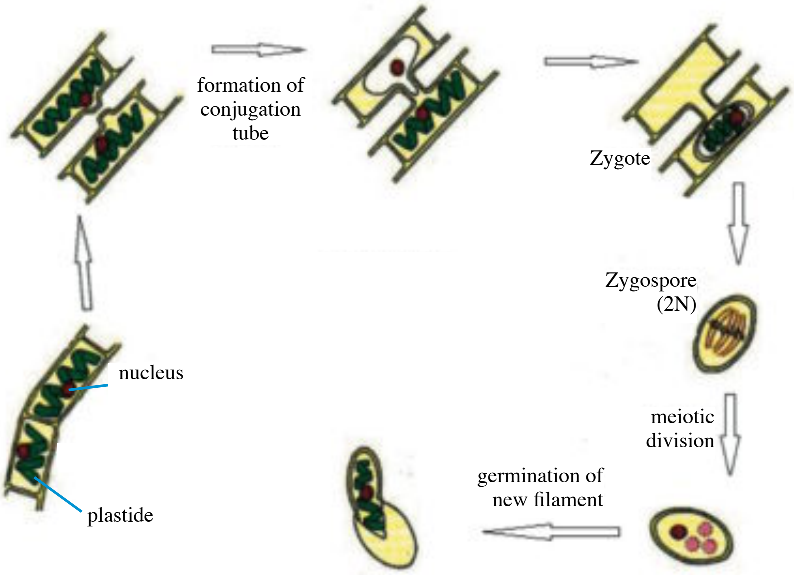


Fig. (9) Scalariform Conjugation in Spirogyra

Zygote becomes coated by a thick wall that protects it along unsuitable conditions and is then called "zygospore". The latter remains dormant till the surrounding conditions improved then the zygospore divides by meiosis to form four haploid cells, three of them degerate and the fourth divides by mitosis to form new filament.

b) Lateral conjugation:

- This conjugation occurs between the adjacent cells of the same filament. The protoplasm of one cell moves to the adjacent cell through an opening in the wall in between them.

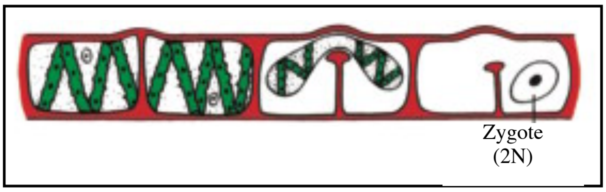


Fig. (10) Lateral corjugation in Spirogyra

- It is to be mentioned that cells of the algae filament are haploid (N), and after conjugation, the zygote (2N) is formed.
- This divides by meiosis before germination of the new filament, leading to haploidy of the algae cells.

2. Reproduction by sexual gametes:

Higher plants and animals reproduce by means of sexual gametes that are differentiated into 2 kinds: male and female gametes. Both are derived from meiosis that takes place in gonads.

The male gametes are characterized by their ability to locomotion. Thus, they are adapted for that function and so lose most of its cytoplasm. The body becomes pointed and provided with a locomotory tail or flagellum to help transport the genetic material to the female gamete during fertilization. Since some of them are subjected to loss during the above process, 4 male gametes are produced from each original cell.

Female gametes that are formed in the ovary usually remain stationary within female body till fertilization. So they are spherical, almost enriched with food, where, they are produced in few numbers.

Male gametes may be transported to the female via water as in aquatic animals like bony fishes and toads. Both the male and female shed their gametes in water where external fertilization occurs and the embryo develops in water. In terrestrial animals, fertilization takes place internally. Sperms should be introduced to the eggs that remain within the female body till fertilization. It means fusion of the male gamete nucleus with that of the female to form the zygote that resumes its diploid (2N) nature and passes towards embryonic development by means of mitosis.

Third: Alternation of generations

Some plants and animals species can breed both asexually and sexually in an alternation of generations during their life cycle. They gain from both methods their advantages of rapid production and genetic diversity. These enable them to disperse widely and to conform with the environmental fluctuations. This may be associated with variation in chromosome number of these generations.

This phenomenon can be shown by the following examples:

1. Life cycle of Plasmodium (Malaria parasite)

This is sporozoan parasite from the Protozoa that infects both man and female Anopheles mosquito. Its life cycle starts when the infected mosquito bites human skin. It pours in his blood minute spindle - shaped Sporozoites. These move towards the liver where they spend an incubation period during which they make 2 cycles of asexual reproduction, their nuclei divide by schizogony giving several Merozoites. These migrate to the blood infecting the red cells where they pass several cycles. They produce huge numbers of Merozoites that are released together every 2 days with the destruction of infected red blood cells and formation of toxic substances. Meanwhile symptoms of Malaria fever appears on the patient (as heat, chill and sweating).

Later, gametocytes arise and migrate to the mosquito with patient's blood where they develop to gametes in mosquito's stomach (Fig. 11) They fuse into a zygote that transforms to Ookinete which penetrates into stomach wall and divides meiotically to give to Oocyst.

The life cycle in female mosquito | The life cycle in man

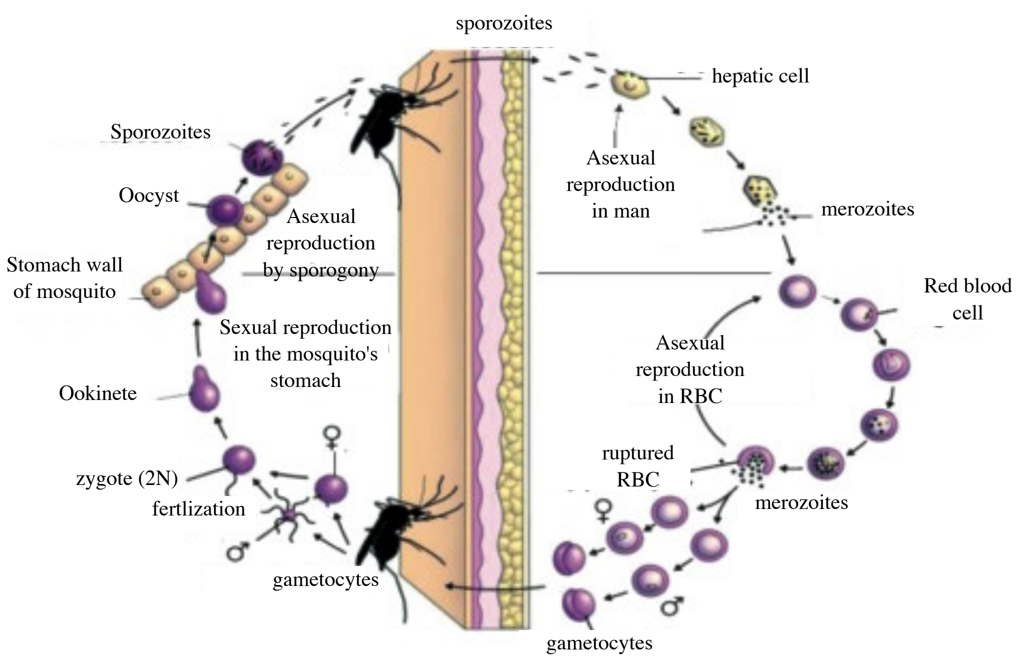


Fig. (11) Life cycle of Plasmodium (Malaria parasite)

Its nucleus is divided by mitosis, this process is known as Sporogony producing numerous sporozoites that liberate and move towards the mosquito's salivary glands to be ready for human infection.

So, the life cycle of plasmodium has a sexual generation that reproduces by gametes (in mosquito) and by schizogony (in man).

2. Life cycle of a fern plant:

From the common ferns, *Polypodium* is known in plant nurseries as an ornamental plant and *Adiantum* which grows on well edges and shaded streams. The life cycle of *Polypodium* plant (Fig. 12) starts by the "sporophyte" which carries the leaves on their lower surfaces of which have the sori. These contain numerous spore mother cells (2N) which divide by meiosis giving the spores (N). On maturation, spores are released and Carried by winds to far distances. Upon settling on a wet soil, the spore germinates forming several cells that develop to a flat heart-shaped body called "gametophyte" that grows over the soil.

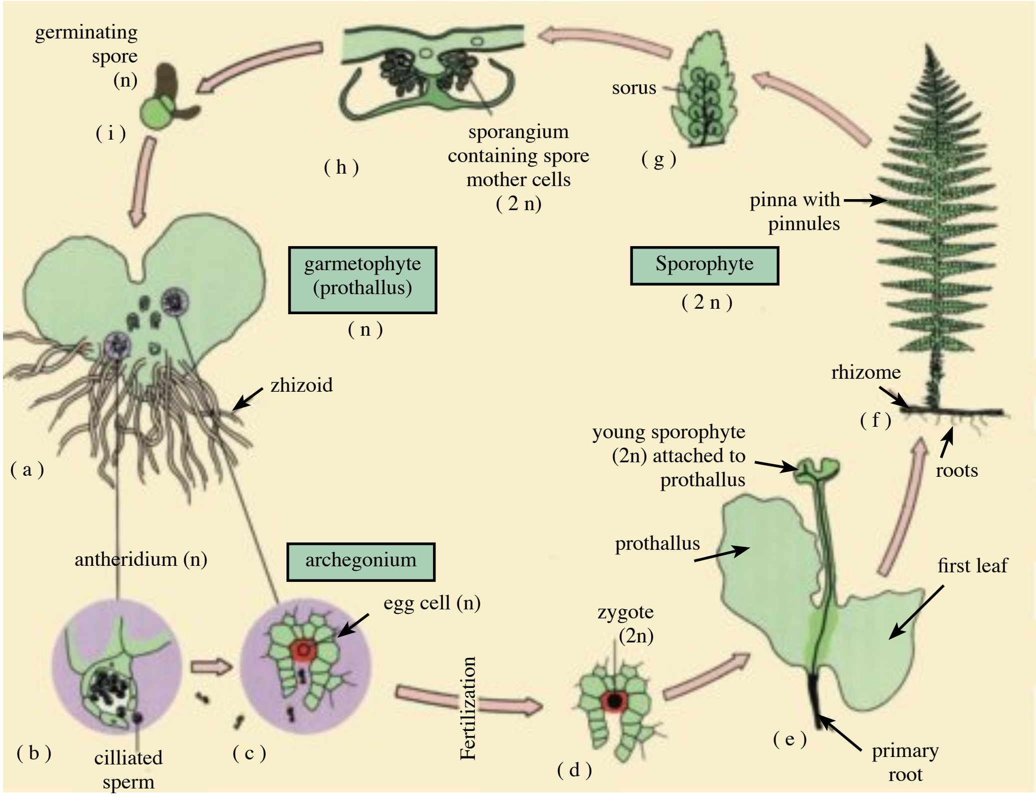


Fig. (12) Life Cycle of Polypodium

From the lower surface extremity of the gametophyte arise the rhizoid processes that penetrate into the soil to absorb water and salts. From anterior region of the same surface of gametophyte grow the genital organs, namely Antheridia (male organs) and Archegonia (female organs). On maturation of Antheridia, the male gametes (ciliated sperms) liberate and swim over soil water to reach the mature Archegonia for fertilizing its egg forming the zygote (2N). This divides and differentiates to a new sporophyte that grows over the gametophyte on which it depends for some time till developing its own roots, stem and leaves. The gametophyte then degenerates while the sporophyte grows to repeat the life cycle. So the sporophyte (2N) that reproduces asezually alternates with the gametophyte (N) that reproduces sexually in the life cycle of ferns. By such way, it represents a typical example of the phenomenon of alternation of generations in the living organisms.

Reproduction in Flowering plants

The flowering plants are a large group of seed plants whose seeds develop with a pericarp. It is then called Angiospermae. They are common in various habitats. They vary in size from small herbs to giant trees. The flower in these plants is the specialized organ for reproduction. It is a short stem with the leaves being modified to various floral parts. The flower arises from the axils of either a green or a scale leaf called bract. In some cases flowers occur without bracts.

Flowers may be solitary apical as in *Tulip*, and so stops the growth of the stem. It may also be solitary axial as in *Petunia*. In other cases, flowers may be grouped on the floral axis into various aggregations called inflorescence as in beans and manthur.

The flower and its parts

The flower emerges (Fig. 13) from the axils of a leaf called bract that varies in shape and colour from a plant to the other. The flower in some plants is carried on a pedicel and so becomes stalked. In some others, it is sessile. A typical or complete flower (such as in beans, apple, onion and petunia) has 4 floral whorls. Leaves of each whorl alternate with that of the next whorl.

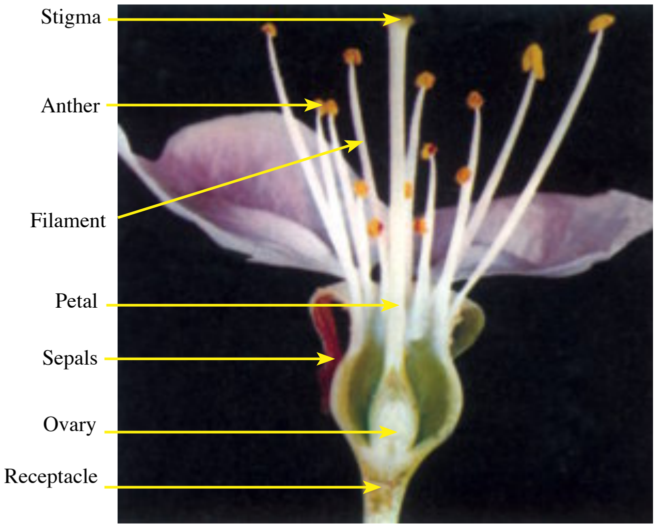


Fig. (13) L.S in the flower

Galyx: It is the outer whorl of the flower, it is formed of green leaves known as sepals. They protect the inner parts of the flower against drought, rain or wind.

Corolla: It is the next whorl inside the calyx. It is composed of one row or more of petals, that help in protection of the floral sexual parts and they attract insects so that, the pollination process occurs.

In flowers of most monocot plants as Tulip and Onion, leaves of the calyx are hardly differentiated from those of the corolla and so both whorls are called perianth.

Androecium: It is the male organ, that consists of numerous leaves called stamens. Each stamen consists of a filament which carries an apical anther that contains 4 sacs of pollen grains.

The Gynoecium: It is the female organ and is the central whorl of the flower and consists of one or more carpels. The carpel's base is swollen and called ovary which contains the ovules. Carpels may fuse or remain separate and enclose one or more lobules. A thin neck attaches over the ovary called the style which ends by a sticky disc called stigma where pollen grains adhere.

Flower Functions:

In order for the flower to perform its functions in reproduction and species continuity, the stamens should prepare for pollen production and the ovary for ovule formation. Then follows the 2 processes of pollination, and fertilization to produce the fruit and the seeds. This can be described as follows:

First: Formation of pollen grains:

If you examine a T.S. in a mature anther of a large stamen as that of the Lily (Fig. 14), you find 4 sacs of pollen grains. During flower development and before formation of pollen grains, these sacs are full of large nucleated diploid cells (2N) called spore mother cells.

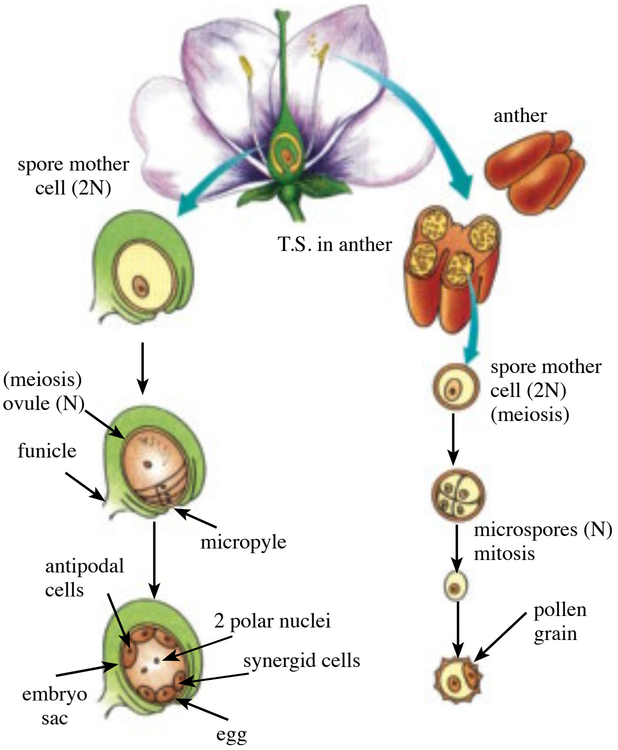


Fig. (14) Maturation of Ovary and Anther stages

- Each of these cells is divided meiotically forming 4 haploid (N) called microspores.

Each of these microspores develops into a pollen grain through a mitotic division of its nucleus into 2 nuclei called the tube and generative nuclei. The wall of the pollen grain then thickens for protection. Meanwhile, the anther matures, and the wall in-between adjacent pollen sacs degenerate. Then the sacs open releasing the pollen grains that become ready for dispersal.

Second: Formation of ovules

During the production of pollen grains in the anther, parallel changes occur in the ovary as follows:

The ovule starts to appear as a simple swelling on the interior ovary wall that contains a large sport mother cell. During the ovule growth a funicle develops connecting it with the ovary wall (through which food material reaches it). Then 2 integuments surround the ovule completely, save a minute hole called micropyle through which the ovule is fertilized.

Within the ovule, the mother spore cell (2N) is divided meiotically giving a row of 4 haploid cells (N). Three of them degenerate and the fourth grows rapidly forming the embryo sac that is surrounded by a nutritive tissue called nucellus, then the following steps are taken place.

1. The nucleus is divided mitotically thrice giving 8 nuclei, 4 of them migrate to each pole of the embryo sac.
2. From each of these 4 nuclei, one moves to the centre of the embryo sac giving the 2 polar nuclei.
3. Each of the remaining 3 nuclei at both of the sac poles becomes enveloped by some of the cytoplasm and a thin membrane forming distinct cells.
4. The middle of the 3 cells that are close to the micropyle grows forming the egg, while the 2 side cells are called synergids. The 3 cells that are distant from the micropyle are called antipodal cells. The ovule by such way becomes ready for fertilization (Fig. 15).

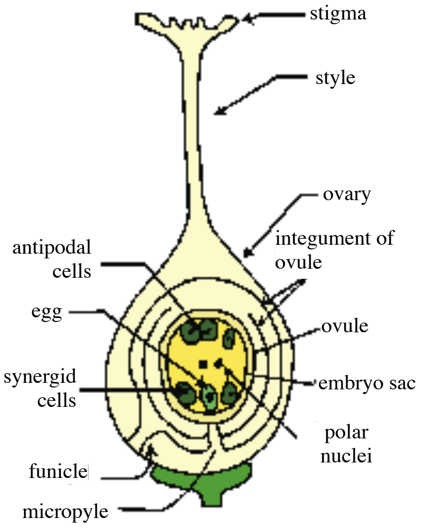


Fig. (15) Section of mature ovary

Third: Pollination and fertilization

a) Pollination

This is the process by which pollen grains are transported from the anther to the stigma of the flower.

■ Types of pollination

1. Self pollination:

The pollen grains are transported from the anther to the stigma of the same flower or to that of another flower of the same plant.

2. Cross pollination:

The pollen grains are transported from the flower anther of a plant to the stigma of another plant of the same species.

- This pollination may occur in plants according to presence of certain factors such as the following:
- Flowers are unisexual.
- Organs of one sex mature before those of the other sex (as in flowers of early maleness or early femalenss).
- Height of anthers is lower than the stigma, cross pollination needs means to be transported from one flower to another such as air, insects, water and man.

b) Fertilization:

This process takes place according to the following stages:

1. Pollen grains germination:

When the pollen grains fall on the stigma, they germinate where the tube nucleus forms the pollen tube, which penetrates the stigma and crosses through the style till it reaches the ovule's micropyle. Then the tube nucleus degenerates while the generative nucleus is divided one mitotic division into 2 male nuclei. (Fig. 16, 17). One male nucleus (N) fuses with the egg nucleus (N)

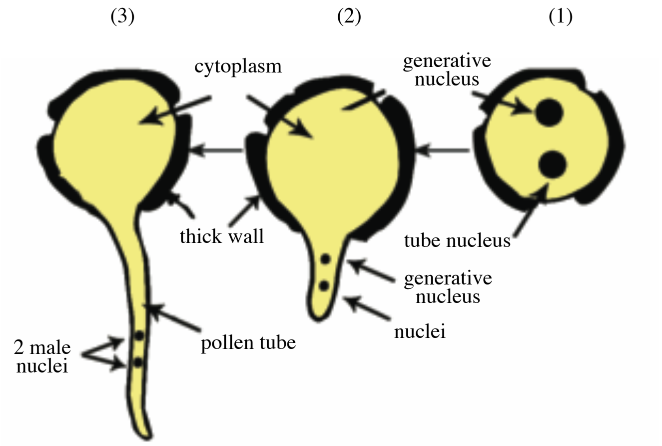


Fig. (16)
Stages of pollen grain germination

Fig. (17)
Pollen grain under the microscope

forming the zygote (2N), which starts to divide forming the embryo (2N) (Fig. 18).

- The second male nucleus (N) fuses with the two nuclei of the embryo sac (2N) forming the endosperm nucleus that becomes triploid (3N).

- The last stage is called the triple fusion.

- The previous two fertilization stages are called the double fertilization.

- The endosperm nucleus is divided, forming the endosperm tissue; that supplies the early developing embryo with food. This tissue may remain outside the embryo occupying a part of the seed.

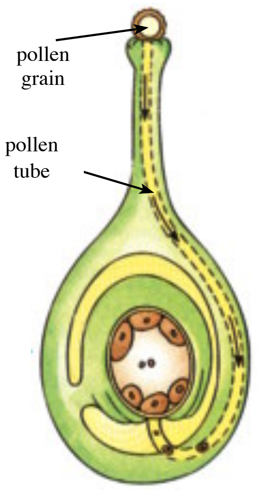


Fig. (18)
Fertilization process

Male nucleus (N) + egg nucleus (N) ⟶ Zygote (2N) ⟶ embryo (2N).

Male nucleus (N) + two nuclei of the embryo sac (2N) ⟶ endosperm nucleus (3N).

2. Formation of fruit and seed

- The embryo may keep the endosperm, the seeds in this case are called (endospermic seeds) such as one cotyledon seeds in which the integuments of the ovary and ovule fuse together forming a single seeded fruit called grain, as in maize and wheat.

- The embryo may feed on the endospermic tissue during its development so it is called (exendospermic seeds), accordingly the plant has to store another food in the cotyledons, hence these seeds are called two cotyledons seeds (dicotyledons), where the integuments of the ovule harden forming the seed testa, it is called (seed), as in bean and pea seeds.

After fertilization, the calyx, the corolla, the androecium, the style and stigma wilt and fall out, only the ovary remains that stores food, ripens, and transformed into fruit due to the hormones (auxins) secreted by ovary.

- The ovary's wall is transformed into the pericarp, and the seed wall into the seed coat or testa.

- The 2 synergid cells and antipodal cells disappear while the micropyle remains so as to allow water to get into the seed during germination.

There are some fruits which keep some parts of the flower - for example:

* Leaflets of the calyx and the stamens remain as in pomegranate.

* The calyx may take part as in egg plant and dates fruits.

* The corolla leaflets may stay as in marrow fruits.

False fruit:

It is the fruit in which any part except its ovary enlarges to store food. As in apple where the receptacle may share in fruit formation.

From the previous we conclude that:

Pollination provides the flower with male cell needed for fertilization of the ovule that develops into the seed. It also stimulates the auxins necessary for developing the ovary into a mature fruit even if fertilization does not take place.

Parthenocarpy:

It is the natural development of fruit that is devoid of seeds since no fertilization takes place as in, banana and pine - apple. That can be carried out artificially by spraying the stigmata with the extract of pollen grains (Pollen grains powder in ether solution or the use of indole or naphthol acetic acid) to stimulate the ovary to form the fruit.

- The maturation of the fruit and seeds often leads to discontinuity of the plant growth and sometimes to its death, especially in annual plants due to consumption of stored food and inhibition of hormones.

If pollination and fertilization do not take place, the flower withers and drops off without fruit formation.

Reproduction in Human Beings

Man belongs to class Mammalia in which the embryo develops inside the uterus till birth. Their eggs are small and nearly devoid of yolk. The number of youngs is few, due to parental care. Man shows a high degree of care, where the young requires several years of raising. This is due to his mental progress that God provided him to be superior over other creatures.

The Male Genital System

It consists of two testes (Fig. 19). Each testis leads to the tubules of the epididymis, the vas deferens, accessory glands till urethera. This system produces sperms and secretes male hormones whose function is to develop the secondary sex characters, i.e. the voice becomes deep, muscles grow stronger and growth of facial hair .... etc.

a) The two testes:

The testis lies outside the body in the scrotal sac. In the course of their development during the last months of pregnancy; they move out of the main body cavity into the scrotum. Such a position prepares a condition cooler than the body temperature. This is suitable for spermatogenesis. Whenever a testis fails to descend down into the scrotum, spermatogenesis does not occur, causing infertility.

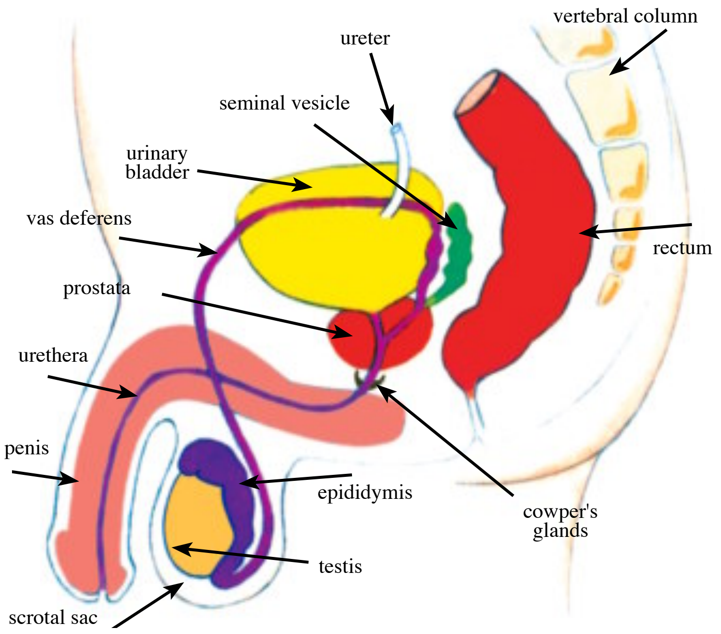


Fig. (19) Male genital system in man

The importance of the testis

1. The production of sperms.
2. The secretion of testosterone hormone which causes the secondary male characteristic to appear at puberty.

b) The two epididymis

Each testis leads to cumulated tube called epididymis, the latter leads to the vas deferens.

c) The two vas deferenses

Each vas deferen transports sperms from the epididymis to the urethera.

d) The two seminal vesicles

Which secrete alkaline fluid containing fructose sugar to nourishe the sperms.

e) Prostate gland and Cowper's glands

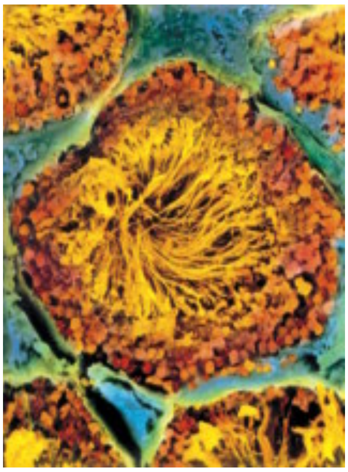
They secrete a sugary fluid (which nourishes sperms) and alkaline fluid to neutralize the acidity in the urethera. Since the neutral medium suits the passage of the sperms in it, therefore the alkaline fluid passes in the urethera just before the sperms.

f) The penis

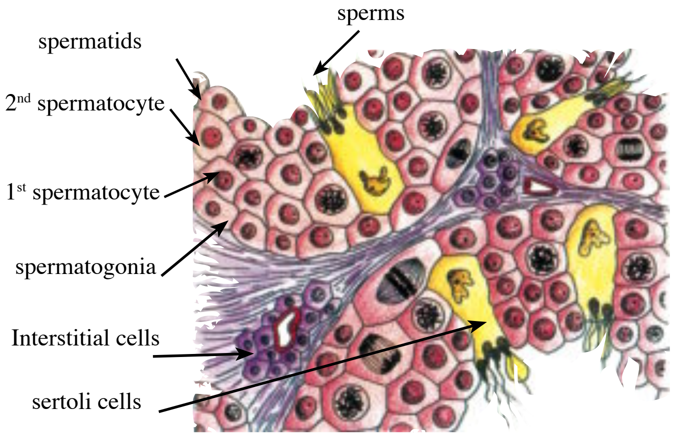
It is a spongy tissue organ that contains the urethera. The urine and sperms are expelled from it separately.

Study of a T.S. of testis

- The testis is built up of seminiferous tubules among them there are interstitial cells which secrete the testosterone hormone.
- Inside each tubule there are sertoli cells which secrete fluid to nourishe the sperms inside the testis. It is supposed that, they gave also immunization function.
- Each tubule is lined internally with primary germ cells (diploid) (2N) they are divided and finally transformed into sperms. (Fig. 20 a, b).



(a)



(b)

Fig. (20) T.S. in the Testis

This process (Fig. 21) passes by four important phases which are:

a) **Multiplication phase:** In which the mitotic division takes place serveral times in the primary germ cells (2N) as a result of this division, a great number of spermatogonia cells (2N) are produced.

b) **Growth phase:** In which the spermatogonia store an amount of food and are transformed into primary spermatocytes (2N).

c) **Maturation phase:** In this stage, the primary spermatocytes (2N) undergo meiosis I, the result being secondary spermatocytes (N) which undergo meiosis II. The resulting cells are haploid spermatids (N). Note that the number of chromosomes is reduced to its half in maturation phase.

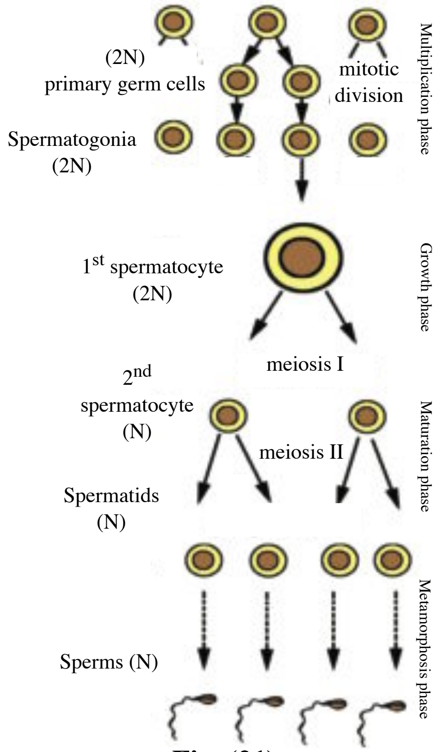


Fig. (21)
Stage of spermatogenesis

d) **Metamorphosis phase:** In this phase the spermatids are changed into sperms.

Structure of sperm:

It consists of:

a) **The head:** It contains the nucleus with 23 chromosomes. There is an acrosome in the forehead which secretes the hyaluronic enzyme that dissolves a part of the ovum membrane, to facilitate its penetration process.

b) **The neck:** It contains two centrioles which play in important role in the fertilized ovum division.

c) **The midpiece:** It contains mitochondria which supply energy for sperm movment.

d) **The tail:** It consists of an axis which ends with caudal piece. It helps the sperm to move.

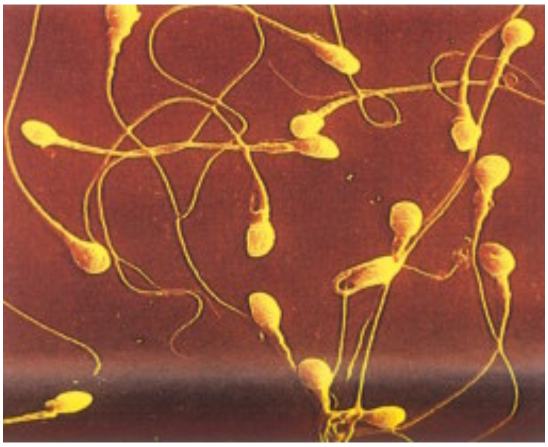


Fig. (22-a) Sperms under the microscope

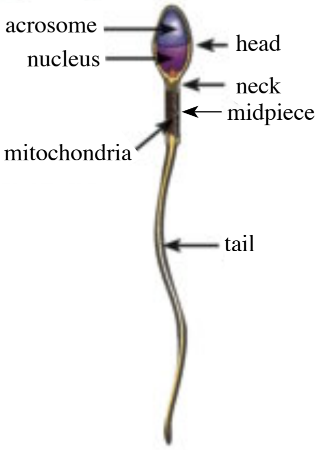


Fig. (22-b) Structure of sperm

The human female genital system:

It consists of two ovaries, two oviducts, the uterus and the vagina.This system produces the ova and the famale sex hormones, besides providing a safe place for completionof fertilization and embryo development till birth (Fig. 23).

The organs of this system lie behind the urinary bladder in the pelvic region. They are firmly connected in this position with elastic ligaments which allows its expansion during pregnancy.

a) **The two ovaries:** They lie on the sides of the pelvic cavity. Each ovary has an oval shape. It equals in size a peeled almond.

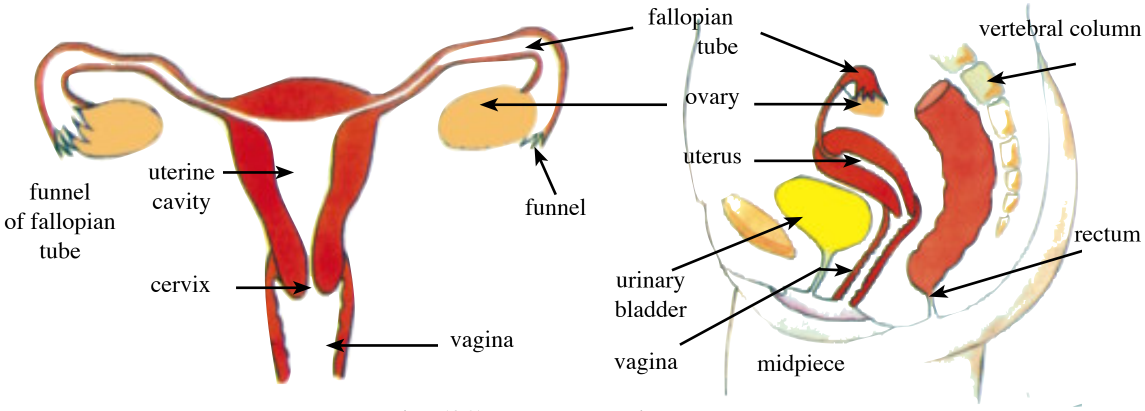


Fig. (23) Female genital system

During childhood each ovary contains several thousands of ova in various stages of development. After maturity about 400 of these ova only will mature during the thirty years of active reproductive life (fecundity years).

From each ovary, one mature ovum is discharged alternately with the other ovary per month.

It secretes the maturation hormones for regulating menstrual cycle and embryo development.

b) The two fallopian tubes: Each oviduct (Fallopian tube) has a funnel shaped opening. It lies just opposite the ovary to insure the fall of ovum in it; besides, it is provided with finger like processes to recieve the ovum, it is lined with cilia to direct the ovum towards the uterus.

c) Uterus: It is an elastic mascular sac-like organ. It lies in the pelvic cavity. It has a thick muscular strong wall, lined with a glandular membrane. The uterus is ended with the cervix which opens to the vagina. The embryo is formed inside the uterus for nine monthes.

d) Vagina: It is a muscular tube, its length is about 7 cm, it starts from the cervix to the genital opening. This tube is lined with glandular membrane that secretes mucous fluid to moisten this membrane glandular, also it has folds to allow its expansion during birth.

As a female approaches maturity (at the age of 12-15 years), a monthly rhythmic changes takes place in the female reproductive system according to the ovarian and uterine activities. Such activities may correlate with fertilization and pregnancy, or non-pregnancy and the monthly bleeding which is termed menstruation. At the age of 45 - 50 years, the ovaries become inactive i.e. the hormonal secretion is decreased, and the uterine lining is wrinkled. This is known as menopause.

Study of T.S. in the ovary:

From this study we notice that the ovary (Fig. 24) consists of a group of cells in different stages and the ovum inside the Graafian follicle. This follicle is transformed into the corpus luteum after the release of the ovum.

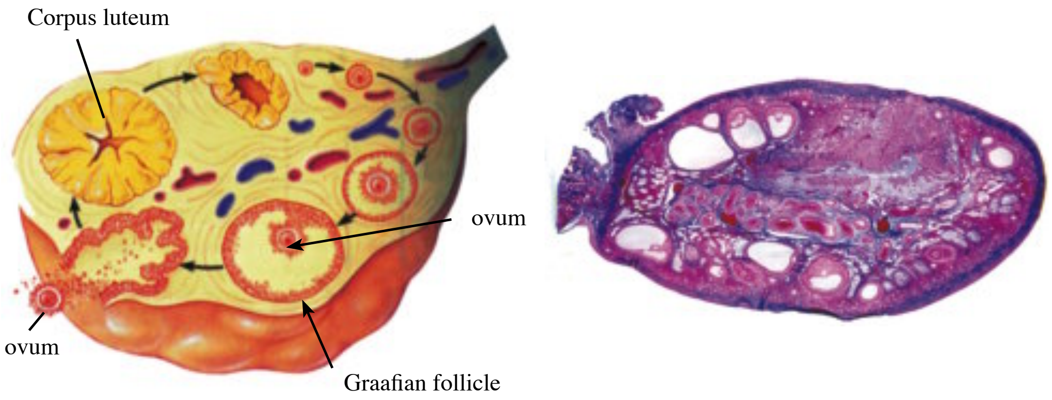


Fig. (24) T.S. in ovary

Stages of oogenesis:

This process passes by three important stages which are (Fig. 25).

a) **Multiplication phase:** In which the mitotic division takes place in the primary germ cells (2N) forming the oogonia (2N). This phase occurs in the embryo.

b) **The growth phase:** The oogonia (2N) store an amount of food, increase in size and are transformed into primary oocyte (2N). This phase occurs in the female embryo.

c) **Maturation phase:** The primary oocyte (2N) is divided by first miotic division into secondary oocyte and Ist polar body, both of them will be haploid (N) and the oocyte is larger than the polar body. Then the secondary oocyte is divided by second meiotic

division giving an ovum and second polar body. The latter polar body is divided by meiotic division into two polar bodies. So the resultant is three polar bodies.

This second meiotic division is done at the moment of entry of the sperm to inside the ovum to complete the fertilization.

The ovum contains cytoplasm and nucleus, it is enveloped with a thin cellular coat, its cells are held together by hyaluronic acid. The enzymes secreted by the acrosomes of sperms dissolved this coat at the penetration positon, therefore millions of sperms are required to penetrate the ovum.

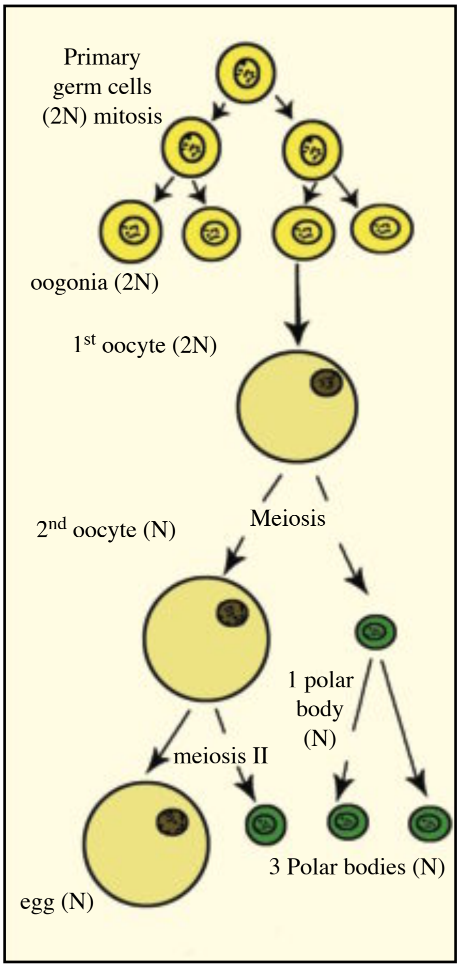


Fig. (25) Stages of oogenesis

Breeding cycle

In the life of placental mammals generally, there are certain periods where the ovary becomes regularly active in the adult female. These cycles are periodic and coincide with the sexual function of mating and production. This is known as breeding cycle. The period of such cycles differs in various mammals. In some mammals such as the lion and tiger, the cycle is annual. Others may have two breeding cycles per year, such as cats and dogs. In some others, such as rabbits and rats, the breeding season occurs frequently per month.

In human beings, such a cycle is known as the menstrual cycle. A typical menstrual cycle is 28 days. The two ovaries alternate with each other to produce mature ovums.

Menstrual cycle

This cycle (Fig. 26) is divided into three phases as follows:

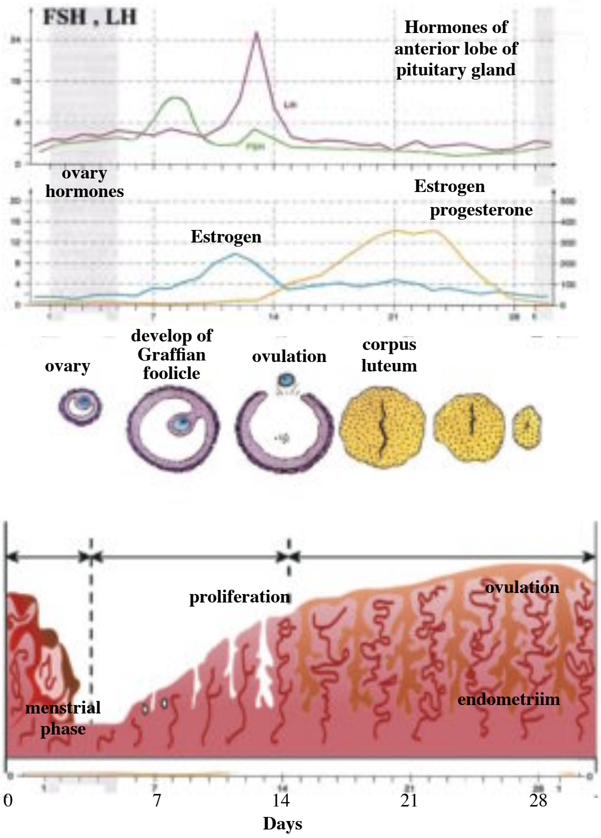


Fig. (26) Diagram of menstrual cycle in women

a) Phase of proliferation: The pituitary gland releases the follicle stimulating hromone (FSH). This stimulates the ovary to form the mature Graafian follicle. The ovum grows and mature inside this follicle within 10 days. The follicle secretes estrogen which stimulates the growth of the endometrium.

b) Phase of ovulation: This phase starts when the anterior lobe of the pituitary gland secretes the luteinizing hormone (L.H.) in 14th day which stimulates the ovum to liberate from the Graafian follicle. So Graafian follicle is transformed into the corpus luteum, which produces progesterone. These hormones increase the thickness of the endometrium, and its blood supply. This phase lasts about 14 days.

c) Phase of menstruation: If the ovum is not fertilized the corpus luteum degenerates gradually. Consequently, the secretion of progesterone stops and so the endometrium degenerates and the blood vessels tear due to the successive contractions of the uterus. Thus menstrual bleeding takes place. This lasts 3-5 days and a new cycle of the other ovary begins.

If the ovum is fertilized, the pregnanacy will occure. The corpus luteum remains to secrete the progesterone. This inhibits ovulation, and thus the menstrual cycle stops till after birth. The corpus luteum reaches to its maximum growth at the end of the third month of pregnancy. It starts to degenerate during the fourth month, when the placenta that grows in the uterus takes over its function in secreting the progesterone, which preserves the endometrium. It also stimulates the maternal mammary glands to develop gradually. So if the corpus luteum is removed before the forth month, abortion occurs.

Fertilization

It is the fusion of the male gamete (sperm) with the female gamete (ovum) to form the zygote, which divides forming the embryo.

- After the ovum is released in the 14th day from the beginning of bleeding it will be ready for fertilization through 1-2 days, Fertilzation takes place in the anterior third part of the fallopian tube.

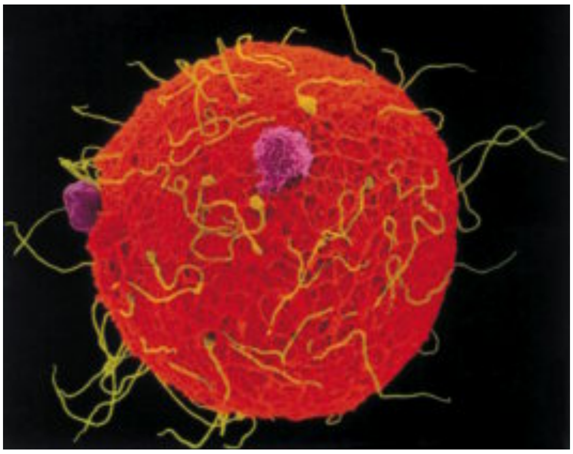


Fig. (27) Fertilization of egg

- The number of sperms ranges between 300-500 millions per ejaculation, many of them are lost during their journey to the ovum, therefore the man is considered infertile if the number of sperms is less than 20 millions.

- The sperms share in secreting the hyaluronic enzyme which dissolves part of the ovum coat through which one sperm only enters (the head and neck only).

- The sperms can stay alive about 2-3 days inside the female genital system.

After fertilization the ovum surrounds itself with a coat, that prevents the entrance of any other sperm.

Pregnancy and embryonic development

By about 24 hours after fertilization, the zygote divides (by mitotic division) to two cells (two blastomeres) in the upper part of fallopian tube, then to four cells in the next day. Latter the cellular division speeds up forming a mass of small cells, known as the morula. This is pushed along the uterine tube by ciliary action and muscle contraction till it reaches the uterus. In the uterus this is implanted among the folds of the thick walled uterus (endometrium), at the end of the first week. (Fig. 28).

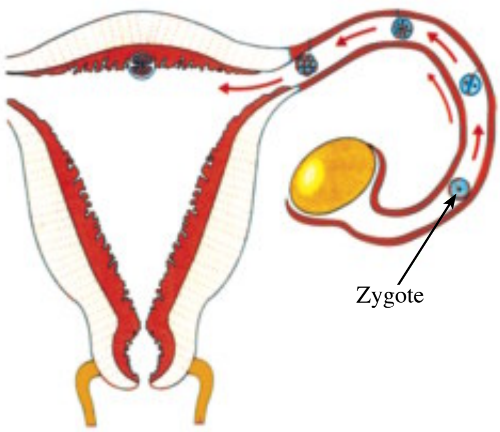


Fig. (28) Splitting of the zygote

The endometrium is characterized by rich blood supply necessary for the development of embryo along the nine months of pregnancy.

Embryonic membranes

The rate of embryo growth is increased. Organogenesis and tissue differentiation gradually takes place. Two embryonic membranes are formed, the outer membrane is the chorion and the inner one is the amnion.

a) **The amnion:** It surrounds the embryo with a fluid serves to protect the embryo against shocks and dryness.

- The embryo is connected with the placenta by the umbilical cord, its length is about 70

cm its length increases to give more freedom for the motility of the embryo.

- The umbilical cord is a tissue rich in blood vessels which transfere digested food, vitamens, water salts and oxygen from the placenta to the embryo's circulation, and it transferes the excretory wastes and carbon dioxide from the embryo's circulation to the placenta.

b) The chorion: It surrounds the amnion, its function is to protect the embryo. Finger - like projections grow from the chorion membrane to be inserted in the endometruim. In which the capillaries of both embryo and mother touch. They intermingle forming the placenta (Fig. 29).

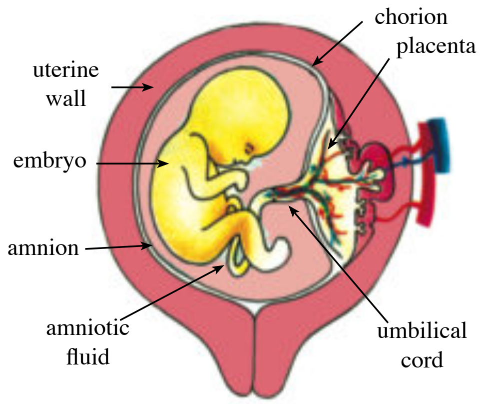


Fig. (29)
Embryonic membranes and embryo

The importance of placenta

1. It transfers digested food, water, oxygen and vitamens from mother's blood to the embryo's blood by diffusion and gets rid of the embryo's excretory wastes. Foetus blood does not normally mix with mother blood.
2. It secretes the progestrone hormone at the beginning of the Fourth month of pregnancy where the corpus luteum degenerates and placenta becomes the source of the progestrose hormone. It also transfers the drugs, harmful substances such as alcohol, nicotine, viruses from mother's blood to the embryo which cause great harms, serious deformities and diseases to the embryo.

The period of embryonic development is divided into three stages which are:

a) The first stage: It includes the first three months of pregnancy in which the nervous system and the heart start their development (in the first month). The hands and eyes become differentiated. Also the two sexes become diferentiated (the testes are developed in the 6th week, and the ovaries in 12th week) and response to stimuli becomes established.

b) The second stage: It includes the middle three months, in which the development of the heart is completed and its beats can be heard. Ossification of the skeletal system

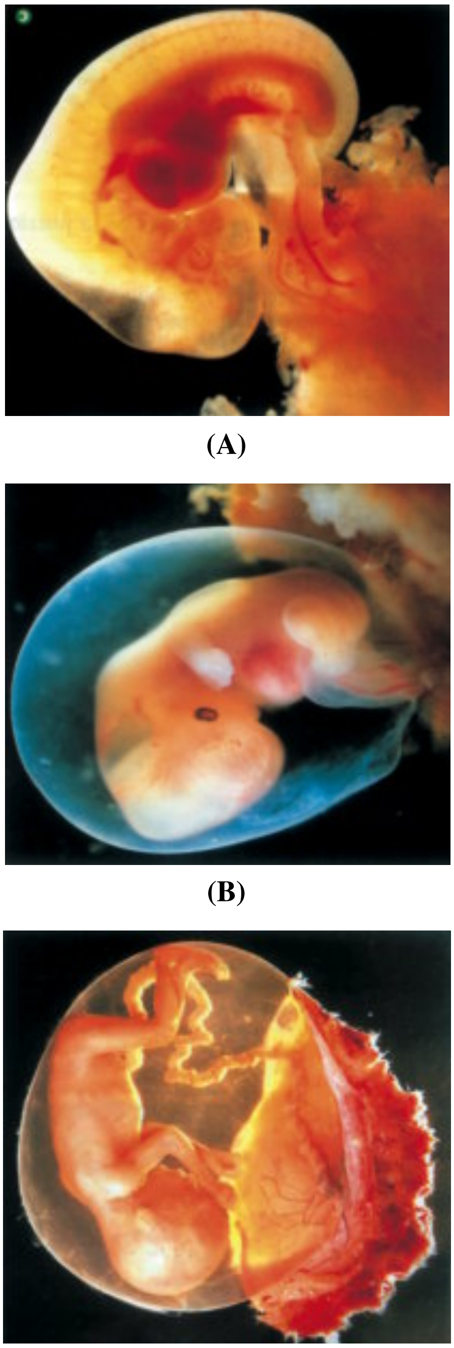
takes place (Fig. 30).

The sense organs are completed and size growth increases.

c) The Last stage: It includes the last three months, in which the development of the brain is completed and the growth slows down, also the development of the other internal system is completed.

- In the ninth month, the placenta dissociates gradually. Thus progesterone decreases and attachment between the foetus and uterus becomes loosened preparing for birth.
- Labor begins with series of contractions in the uterine wall till the foetus is expelled outside.
- The baby starts his life with a distinct cry, which stimulates the respiatory system.
- The placenta separates from the uterine wall and moves outside the body then the umbilical cord is cut from the baby side, and the food supply of the new born changes to the mother's milk. The pituitary hormone stimulats the production of milk in the mammary glands of the mother, milk flows out to feed the baby with the most valuable nutritive and emotional supply, protecting him from many somatic and psychic diseases in his future.

It was noticed that the suitable female age for pregnancy ranges between 18 and 35 years.



(A)

(B)

(C)

Fig. (30)
The stages of embryonic development

If the age decreases or exceeds that range, both the mother and the embryo will be subjected to serious problems, more over, the possibility to produce deformed babies will increase. On the other hand, if the father is too old, similar results will occur to his babies.

N.B. The time of pregnancy differs according to the kind of organism, it is 150 days for sheep, 270 days for man. .

Means of contraceptive

Several contraceptive motheds are used in birth control.

1. **The pills:** They contain a combination of synthetic estrogen and progesterone hormones. Women start using them after the menstrual cycle and continue for 3 week. These pills prevent pregnancy by inhibiting ovulation.
2. **The intrauterine device (the coil):** It is inserted into the lumen of the uterus. It prevents the fertilized ovum to be implanted in the uterus.
3. **Condum:** It prevents the sperms from entering the vagina.
4. **Surgical sterilization :** It involves the ligation of the two fallopian tubes in the woman and cutting them. So, fertilization does not occur for the ova produced by the ovary.

In a similar way in the man where each vas deferens is tied, separated from other structures and is cut. So, no sperms will come out.

Multiple births

Usually, one baby is born in each brith. Sometimes, multiple births take place reaching six babies in the same time. The most common are the twins. The international percentage of twins is once in about 86 briths. (Multiple births are rare).

There are two types of twins.

a) Fraternal (dizygotic) twins:

Two mature ova are liberated (from one or both ovaries) at the same time. The two ova are fertilized (with two sperms), and each one will develop to an independent embryo. The two embryos differ genetically from each other. Each embryo has its own embryonic sac and separate placenta in the urerus (Fig. 31). They never exceed brothers of the same age.

Fig. (31) Identical twins

b) Identical (Monozygotic) twins :

This type of twins results from the fertilization of one ovum by a single sperm. The developing cell separates into two masses of cells, each of which develops independently. They form two embryos, identical genetically and share one embryonic sac and mostly one placenta (Fig. 32). They have the same genetic characters. These twins may be born partially attached to each other

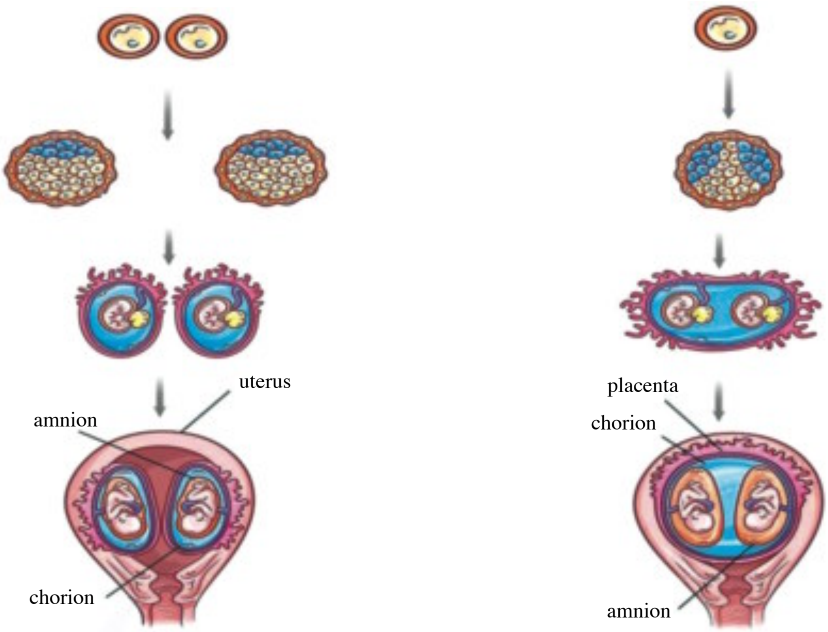


Fig. (32 - a) Fraternal twins **Fig. (32 - b) Identical twins**

at some places of the body. A case known as siames twins which can be surgically separated in most cases.

Test tube babies

A mature ovum is obtained from a wife's ovary and being fertilized externally with the husband's semen inside test tube in a certain nutritive medium till reaches to the morula.

Then it is reimplanted in the wife's uterus to complete its embryonic development till birth (Fig. 33).

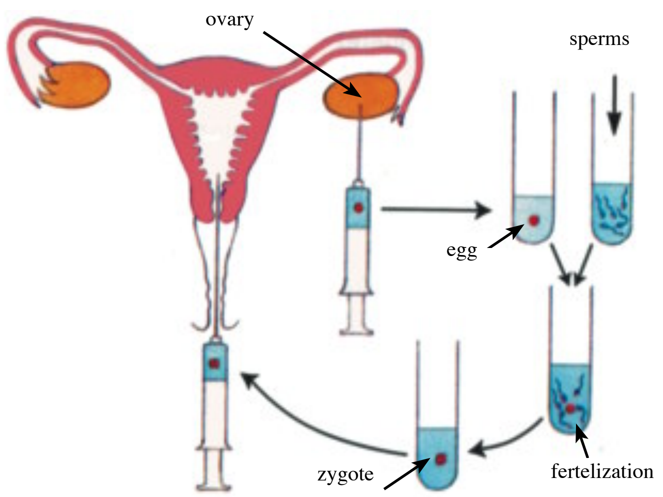


Fig. (33) Test tube babies

Renucleation

Experiments have been conducted on frogs and mice.

Nuclei from amphibian (toad) embryonic cells at diffetent stages of development were removed and transplanted into unfertilized amphibian (toad) eggs, whose nuclei had been removed or destroyed by radiation. Normal development was proceeded giving rise to individuals identical in characters to the individual from which the cultured nuclei were taken. This proves that the early embryonic cell nucleus is capable to direct the embryonic development in a manner similar to that of the zygote nucleus itself.

Gamete banks

Gamete banks are found in some European and American countries. These banks are used to store selected animal gametes especially those of cattle and horses to keep them available for reproduction till the time of need. The gametes are stored in a frozen condition (-120°C) for up to 20 years. After that period they can be used in artificial fertilization, even after the death of the producer individuals or if some rare animal species are liable to extinction. Also, certain people desire to store their gametes in such banks, to ensure the continuity of their generations, even after their death with several years.

On farm animals researches are carried out to control the sex of their newborn. Since it is possible to separate the sperms with (X) chromosome from sperms with (Y) chromosome by laboratory means such as centrifugation or exposure to a limited electric field. This aims to apply such techniques first on cattle to produce only males for meat or females for reproduction and milk production as required by breeders.

Could such technique succeed in case of man?

Practical Activities

1. Microscopical examination of budding in yeast fungus.
2. Microscopical examination of bread mould fungus.
3. Examination of a mushroom fungus.
4. Microscopical examination of conjucation in spirogyra alga.
5. Examination of a gametophyte and sporophyte in *Polypodium*.
6. Examination of the structure of a typical flower.
7. Microscopical examination of a section in anthers and pollen grains.
8. Microscopical examination of a section in ovary of a flower to know its components.
9. Examination of some fruits as tomato, eggplant, apple and marrow.
10. Examination of a section in ovary of rabbit or rat.
11. Examination of a section in a testes of a rabbit or rat.
12. Watching films about stages of embryo formation inside the uterus.

Questions

1. Choose the most accurate answer for the following questions:

1. The average range in which the ovum stay alive inside fallopian tube is :

a) one hour. b) one day
c) 1-2 days. d) 3 days.

2. The average interval in which the sperm stay alive inside female gential system is:

a) one hour. b) one day
c) 1-2 days. d) 2-3 days.

3. The fertilization of the ovum occurs in:

a) uterus.
b) The upper part of fallopian tube.
c) The last half of fallopian tube.
d) The ovary.

4. For the adult woman where the menstrual cycle is 28 days, the phase of ovulation occurs in:

a) The 9th day from the beginning of this cycle.
b) The 14th day from the beginning of this cycle.
c) The 9th day from the end of the cycle.
d) The 12th day from the beginning of this cycle.

5. The ovum inserted in the endometrium after:

a) one day after fertilization.
b) 7 days after fertilization.
c) 4 days after fertilization.
d) 5 hours after fertilization.

6. FSH and LH hormones are secreted from:

a) The Graafian follicle.

b) The corpus luteum.

c) The endometrium.

d) The pituitary gland.

7. From the functions of LH hormone is:

a) Ovulation.

b) The development of the Graafian follicl.

c) The atrophy of corpus luteum.

d) The development of mammary glands.

2. From the fellowing substances:

1. Which of the following substances is transferred from the mother's blood to the embryo's blood through the placenta?:

a) glucose.
b) alcohol.
c) estrogen hormones.
d) anti-bodies.
e) viruses.
f) red blood cells.
g) amino acids
h) oxygen.

2. The spermatozoons cannot live except in nutritive medium, because they cannot store food inside them.

a) The two statements are right and are related to each other.

b) The two statements are right but not related to each other.

c) The two statments are false.

d) The 1^{st} statement is right and the 2^{nd} is false.

e) The 1^{st} statement is false and the 2^{nd} is right.

3. The secretion of the progesterone hormone begins after three monthes from pregnancy because the ovary only secrets this hormone.

a) The two statements are right and are related to each other.

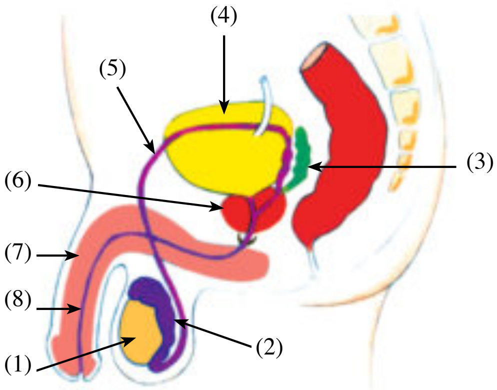
b) The two statements are right but not related to each other.

c) The two statments are false.

d) The 1^{st} statement is right and the 2^{nd} is false.

e) The 1^{st} statement is false and the 2^{nd} is right.

3. Examine the opposite figure, then answer the following:



a) Label the numbered parts.

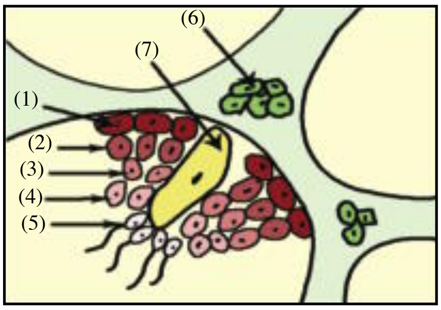
b) What is the part outside the genital system structure?

c) What is the importance of the parts Nº. 3 and 6?

d) What will happen if the organ Nº. 1, lies inside the body? Why?

e) What would happen if the organ Nº. 1 is eradicated?

4. Examine the opposite figure, then answer the following:



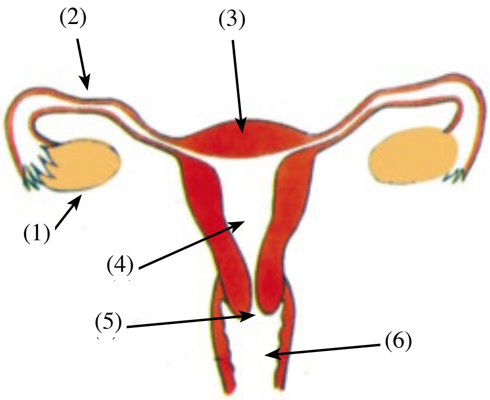
a) Label the numbred parts.

b) Mention the stages of spermatogenesis.

c) Clarify the importance of cells Nº6 and Nº7.

d) Show by labelled drawing the structure of the sperm.

5. Examine the opposite figure, then answer the following:



a) Label the numbered parts (organs).

b) What are the importance of the organs Nº1 and Nº4?.

c) Where does the fertilization process occur?

d) What are the changes which occur to organ Nº1 during the menstrual cycle?

e) What will happen if the two ovaries are eradicated from a pregnant woman? And why?

6. Give reasons for the following:

1. The spermatognesis in the bee male is formed by mitotic division, not by meiotic division.
2. Somtimes, the spirogyra recurs the lateral conjugation.
3. The regeneration in Hydra differs from that in Crustacea.
4. Conjugation in Spirogyra is followed by meiotic division.
5. An extract of pollen grains is spreaded over stigmata of some flowers.
6. The endosperm nucleus is triploid (3N).
7. The cattle sperms are treated by centrifugation.
8. The importance of the midpiece of the sperm during the ovum fertilization.
9. The corpus luteum degenerates during the fourth month of pregnancy, however no abortion occurs.
10. The sperms must be of huge number so that fertilization takes place.
11. As soon as the ovum is fertilized the endometrium and its glands grow.
12. In most mammals, the two testes lay outside the body.

7. What happens in the following cases:

1. The corpus luteum degenerates in the second month of pregnancy.
2. The two testes lay inside the human body.
3. If the two ova are feratilized by two sperms at the same time.

8. Compare between:

a) The gametophyte and sporophyte in the plant Adiantum.
b) Parthenogenesis and parthenocarpy.
c) LH hormone and FSH hormone.
d) The identical twins and the fraternal twins.

9. Some living organisms reproduce by sexual followed by asexual one in their life cycle.

a) What is the scientific term of this statement and how can they make use of it?

b) Why is it common between parasites?

c) Mention two examples, one from the plant kingdom and the other from the animal kingdom in which this phenomenon occurs.

10. In the uterus, the embyro is surrounded by two types of embryonic membranes, what are they? And what is the importance of each?.

11. Using the opposite drawing, answer the following:

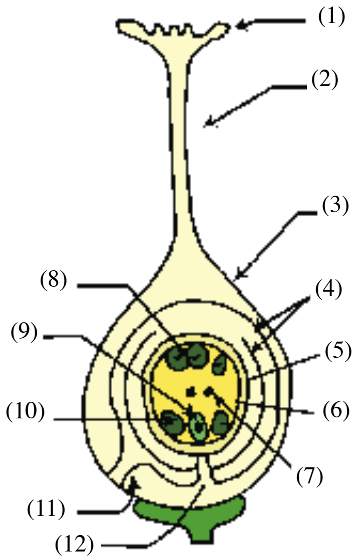
a) Label the numbered organs.

b) How is the seed formed? And how its kind, monocot plants or dicot plants, is determined?

c) What will happen if the flower is not pollinated?.

d) What will happen if the flower is pollinated and not fertilized?

e) How can you get seedless fruits artificially?



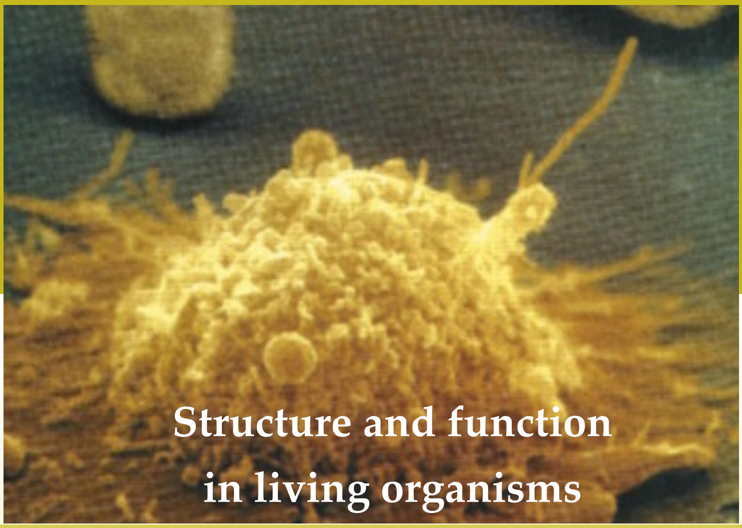
12. Write the name of the hormone which leads to:

1. The growth of the Graafian follicle in the ovary.
2. The follicle rupture and the ovum liberation.
3. The appearanceof the male secondary sex characters.
4. The inhibition of the ovulation and growth of the endometrium.

13. What is meant by each of the following:

Breeding cycle - parthenogenesis - parthenocarpy - double feretilization - corpus luteum - triple fusions - false fruit - Amnion.

14. Show by drawing only the stages of maturation of a plant's ovule (egg) in order for the plant's flower to become ready for fertilization.

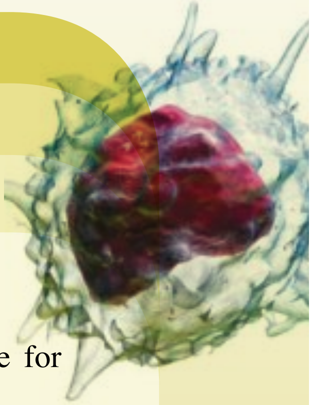


Structure and function in living organisms

Chapter Four

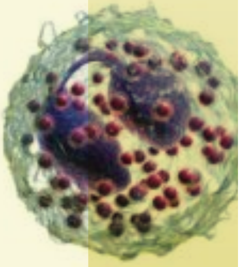
Immunity in Living organisms

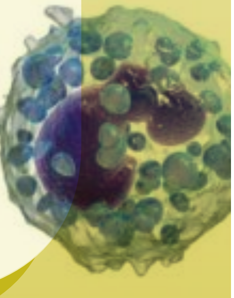
• Learning outcomes

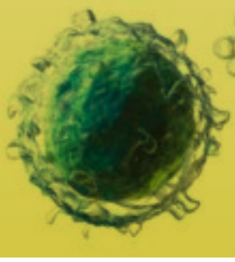


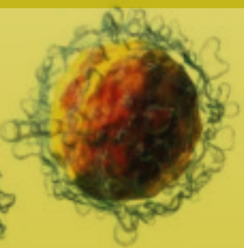
At the end of this chapter the student should be able to :

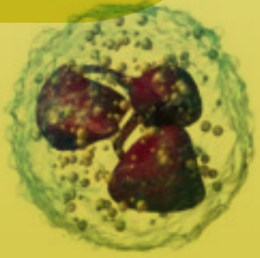
- Recognize the concept of immunity and its importance.
- Recognize the concept of the immune system and its importance for living organisms.
- Compare between the natural immunity and acquired immunity.
- List the pathogens of the plant
- Explain how the immune system works in the plant
- Recognize the structural immunity and the biochemical immunity of the plants.
- Determine the organs of the immune system in humans
- List lymphatic organs in human.
- Determine the types of lymphocytes.
- Identify antibodies and explain their methods of action.
- Explain the mechanism of action of the immune system in humans.
- Identify some means of the natural immunity.
- Appreciate the stunning advances the scientists made in the field of immunology.
- Estimate the grandeur of Allah in the role of some organs of the body to protect it from microbes.











Immunity in living organisms

Introduction:

The life of any living organism is exposed to a continuous threat either from biological sources such as pathogens including some insects, animal, protozoa, fungi, bacteria, viruses, or other non-biological sources such as accidents, natural disasters, disturbance of the surrounding elements of the environment. On the other hand, every kind of living organisms developed defense mechanisms to survive, from these mechanisms are the change of color for camouflage and the secretion of toxins to kill other organisms, or running to escape.

Therefore, the living organisms in a continuous conflict with life- threatening dangers , so God has endowed these organisms elaborate methods of defense, these methods are always changing to face the changing methods of the enemy , From the above, immunity can be defined as the body's ability through the immune system to resist the pathogens, whether through preventing the entry of pathogens into the body of the organism or by attacking the pathogen and foreign bodies and destroy them when entering the body of the organism.

The immune system works according to two systems which are the **Innate immunity** and **Acquired or adaptive immunity**. These two immunity systems are work in cooperation and coordination with each other, as the innate immunity is essential for the acquired immunity to work successfully, and vice versa,this correlation allows the body to act with pathogens.

Immunity in Plant

The causes of disease and death in plants are limited to three main reasons:

1. **The dangerous enemies:** including the grazing animals, insects, fungi, bacteria and viruses .... etc.
2. **The unsuitable conditions:** including high temperatures, excessive cold, increase or decrease in the amount of water and deficiency of nutrients, and unsuitable soil ..etc.
3. **The toxic substances:** such as smoke and toxic fumes, insecticides, the untreated sewage, and flowing from factories to the rivers and irrigation water.

The first factor often causes severe damage destroying the life of the plant or causing dangerous diseases, whereas the results of the second and third factors can be avoided or treated by demise their causes, although some elements of the third reason may be lethal to the plant.

How does the immune system work in the plant?

The plants defend themselves against pathogens through two ways; the first way is the achievement of some mechanisms through their own structures known as Structural immunity and the second way by responding to secrete chemical substances known as Biochemical immunity.

Due to the importance of the plants to humans, so, the human uses methods and introduces means to protect the plant from diseases such as the using of the herbicides to protect the plant from the harmful weeds, as well as struggling with the insects in different ways or stimulating the plant to resist disease known as **acquired immunity** and producing strains of plants resistant to diseases and insects through plant breeding or by using the genetic engineering.

The activation compounds of protection and resistance can transfer from one cell to another in a regular manner through the transport system in the plant which corresponds to the blood vessels in animals.

First: The Structural immunity:

It acts as the first line of defence to prevent pathogens from entering and spreading inside the plant, It is a natural barriers which include two types:

a) The structural immune pre-existing in the plant (Pre-existing structural defences).

b) The structural immune resulting as response to an infection (Induced structural defences)

A) Pre-existing structural defenses

This structural defences is represented by the following:

1. The epidermal cells of the plant.

The epidermis act as the first bulwark in the resistance. They may be covered with waxy layer forming water-repellent surface so, the water does not settle on the surface, therefore the suitable environment for growth of fungi and reproduction of bacteria is not available.

Also, the epidermis may be covered with hairs and thorns to avoid the accumulation of water or being eaten by grazing animals and thus the chance of infections with disease decreased.

2. The cell wall:

The cell wall represents the outer protection of the cells, especially the epidermal layer, which consists mainly of cellulose, and after thickening by lignin that makes it so difficult for the pathogens to penetrate.

B) Induced structural defences

It is represented by the following:

1. The cork formation

The cork layers are formed to isolate areas that exposed to cut or tearing due to the increase in the thickening of the plant during its growth , the collection of fruits, because of the fall of the leaves in the autumn or due to the human and animal encroachment, and that prevents the entry of the pathogen to plant.

2. The Formation of tyloses

Tyloses are overgrowths of the protoplast of adjacent living parenchymatous cells which protrude into xylem vessels and tracheid through pits. They formed as the result of exposure of the vascular system to cut or to invasion of pathogens, to obstruct the movement of these organisms to the other parts of the plant.

3. The Deposition of gums

The infected plants by wounds or cuttings secrete the gum within the cells surrounding the locus of infection, to prevent the entry of microbes inside the plant.

4. Cellular immune structures

Some morphological changes occur as a result of the invasion, such as:

- Swelling the cell walls of the epidermal cells and the cells under the epidermis during the direct penetration of the pathogen, leading to inhibition of the penetration process through those cells.
- Surrounding the mycelium which attack the plant with an insulator cover to prevent the transmission of the fungus from cell to another.

5. Getting rid of the injured tissue

The plant gets rid of the infected tissue, also known as Hypersensitive Response, thus the plant kills some tissues to prevent pathogen to spread to the surrounding tissues so, the plant can get rid of the pathogen by the death of the injured tissue.

Second: The Biochemical immunity (Biochemical defences)

The Immunological mechanisms include the following:

1. The Receptors that recognize the presence of the pathogen and activate the plant defenses.

These compounds are found in healthy and infected plants, but the concentration increases in the plants after the infection.

The function of these compounds are stimulating the Innate immune system in the plant.

2. Antimicrobial chemicals:

Some plants secrete chemical compounds to resist pathogens.

These compounds may be already found in the plant before the infection or formed due to the infection. From these compounds:

- **Phenols, Glycosides:** They are toxic chemical compounds that kill pathogenic organisms such as bacteria or inhibit their growth.

- **Production of non-protein amino acids:** These acids do not enter in the structure of proteins in the plants, but they act as a protective substance for the plant, they include toxic chemical compounds to the pathogens, for example Canavanine and Cephalosporin

3. Antimicrobial proteins

Some plants produce proteins that were not present in the plant but the produced as a result of infection and react with the toxins produced by pathogenic organisms and change it into a non-toxic compounds to the plant. Sometimes the plants produce some enzymes known as Detoxifying enzymes, where these enzymes interact with the toxins produced by pathogens and invalidate their toxicity.

4. Inducible post-infection

Some plants promote and strengthen their defences after the infection in order to protect themselves from any new infection.

Immunity in human

Human immune system

The organs of the immune system are positioned throughout the body.

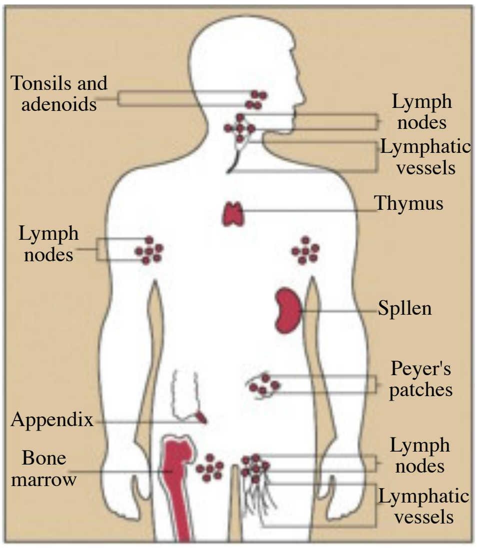


Fig. (1) Human immune system

The parts of this system are scattered, means its parts are not linked to each other in anatomical succession as that in digestive system , respiratory system or circulatory system, it consists of different parts throughout the body, but they interact and cooperate with each other in a coordinated manner. So the organs of the immune system functionally act as one unit and called the lymphoid organ because they are home to lymphocytes, which are the main components of the lymphatic system which consists of the following.

Firstly: The Lymphoid organs

These organs contain large numbers of lymphocytes where maturation and differentiation of lymphocytes take place, from these organs:

a) Bone marrow

It is a tissue inside the flat bones such as the clavicle, the sternum , the skull, the vertebral column , the ribs, the shoulder, the pelvis, and also the heads of the long

bones as the bones of the femur, the tibia and the humerus, which are responsible for the production of red blood cells, white blood cells, and blood platelets.

b) Thymus gland:

It is located on the trachea above the heart and behind the sternum bone, and secrete Thymosin hormone that stimulates maturity of lymphoid stem cells to T- cells and their differentiation into different types inside the Thymus gland.

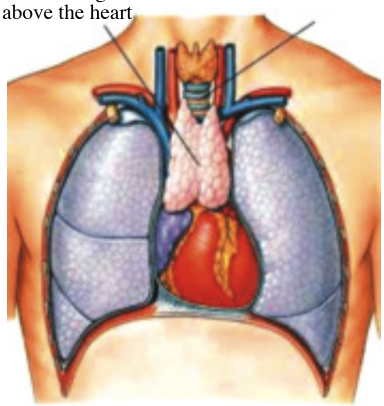


Fig. (2) Thymus gland

c) The spleen:

It is a small lymphoid organ, it's size is not more than the hand palm, and its dark red and located in the upper left side of the abdominal cavity (fig. 3). It plays an important role in the body's immunity, since it has a lot of white blood cells called macrophages which pick up all that is strange about the body, whether microbes or foreign bodies or senescent somatic cells as that of senescent red blood cells and disintegrate it to its components to be disposed by the body, and also contains other white blood cells called lymphocytes, which release a special proteins in the blood known as anti-bodies which holds the defense of the mission which defend the body against germs and viruses

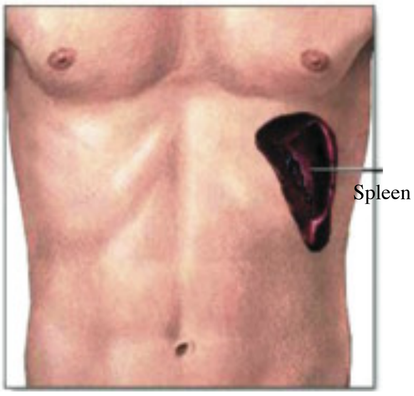


Fig. (3) The spleen

d) Tonsils:

Tonsils are two lymphoid glands located on both sides of the rear portion of the mouth. The tonsils pick up any microbe or foreign body that may enter with food or air and prevent its entry into the body, and thus works to protect the body (Fig 4).

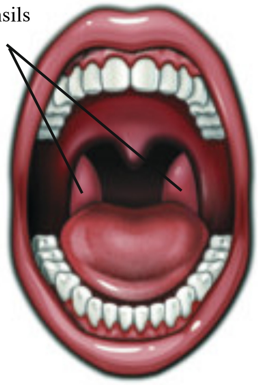


Fig. (4) Tonsils

e) Peyer's patches

A small lymphoid cells that accumulate in the form of masses or aggregations spread to the mucous membrane lining the lower part of the small intestine. Their full function is unknown, but they play a role in the immune response against pathogenic microorganisms that enter the intestine.

f) The lymph nodes

They purify the lymph from any harmful substances or microbes and store white blood cells (lymphocytes) that help in fighting against any disease or infection.

The lymph nodes present along network of the lymphatic vessels that located in all the body parts under the armpits, at the two sides of the neck ,in upper thigh, and near the internal body's organs.

Their size ranging from a pinhead, to the seed of small beans.

The node is divided internally into pockets filled with B- lymphocytes, T- lymphocytes, and macrophages and some other types of white blood cells that get rid of germs and the debris cells.

Each lymph node is connected with several lymph vessels that transfer the lymph from the tissue to the nodes for the filtration of the lymph to get rid the suspended foreign pathogen away from the body.

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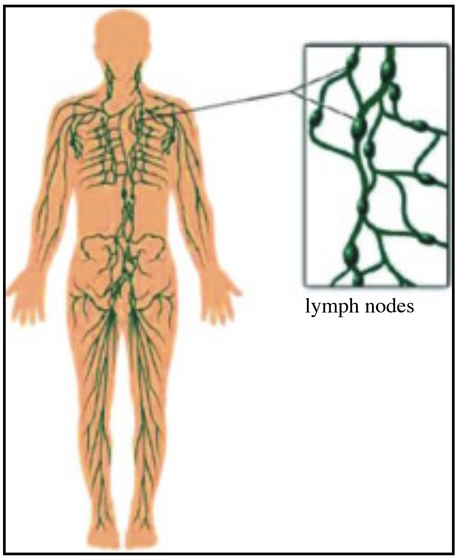


Fig. (5) Lymphatic system and lymph node

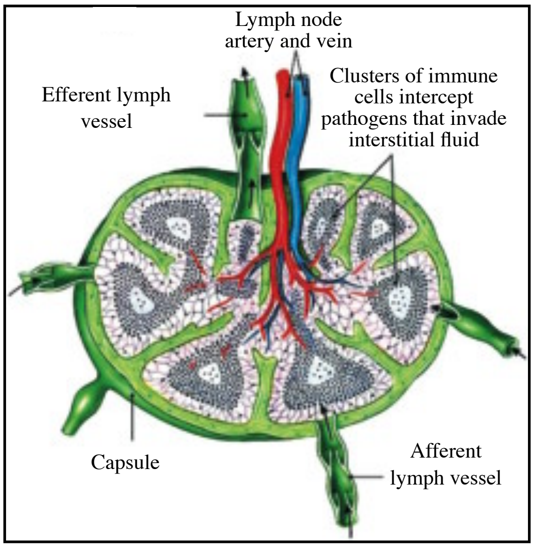


Fig. (6) Lymph node dissection

Secondly: The Lymphocytes

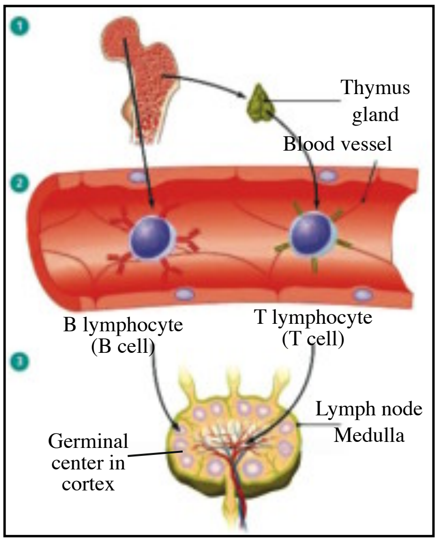


Fig. (7) The sites of formation and maturation of lymphocytes

They form about 20% : 30% of the white blood cells in blood, All Lymphocytes are formed in the red bone marrow,

At the beginning they do not have any immune ability, but they pass in the process of maturation and differentiated in the lymphoid organs after that it changes into cells that have the ability of immunization.(Fig. 7)

They revolve in the blood to research for any microbe or foreign body, their defense and immune mechanisms to get rid of the pathogenic microbes to invade the body, reproduce, and spread through it and sabotage its tissue and disruption of its vital physiological functions.

There are three types of lymphocytes in the blood which are:

a) B- cells: represents 10-15% of the lymphatic cells are formed in the bone marrow and complete their growth to become mature. Their function is the identifying any microbes or foreign materials (such as bacteria or virus), then adhere this foreign material and produces antibodies for his material to destroyed it.

b) T- cells: form about 80% of lymphocytes, and mature in the thymus gland where they differentiate into several types:

1. **Helper T cells (T_H):** activate other types of T cells and stimulate it to do their responses, as well as stimulate B cells to produce antibodies
2. **Cytotoxic T-cells: (or killer T cell) (Tc):** attacking to the foreign cells where. It kills carcinogenic cells , the transplanted organs and body cells infected with the virus.
3. **Suppressor T-cells (Ts):** They regulate the degree of immune response required to limit and discourage or inhibit the action of T cells and B cells after elimination the pathogen.

c) **Natural killer cells (NK):** form about 5% to 10% of lymphocytes in blood, and they are produced and mature in the bone marrow.

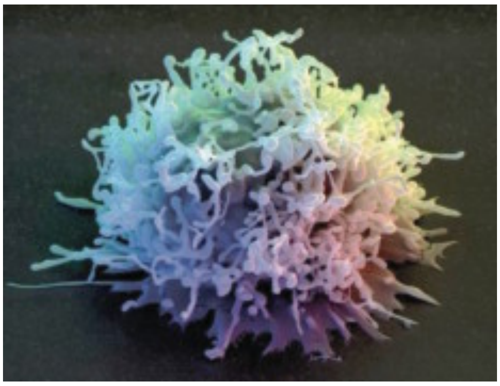


Fig. (8) Natural killer cells

Thurthly: The other white blood cells

They are the basal cell (Basophils), acidic cells (Eosinophils) and neutral cells (Neutrophils).They are distinguishable from their size and the shape of the nucleus and the color of granules phenomenon appeared inside by using the microscope. These granules have the main role in the disintegration of the pathogen's cells attacking the body, ingest and digest the pathogens (phagocytosis) so they struggle the infection specially, the bacterial infection and inflammations. They still in the blood circulation for a relatively short period ranging from several hours to several days. This, in addition to a single-core Monocytes cells that destroy foreign bodies, and change into phagocyte cells when needed, and engulf the foreign organisms.

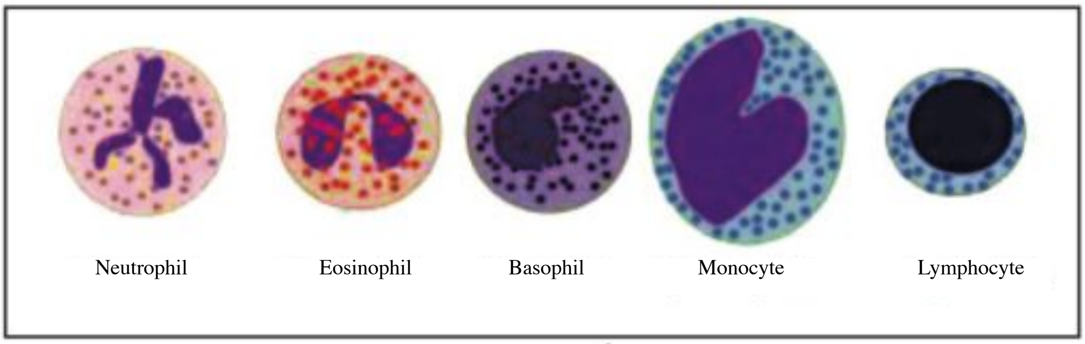


Fig. (9) The other white blood cells

Fourthly: Macrophages

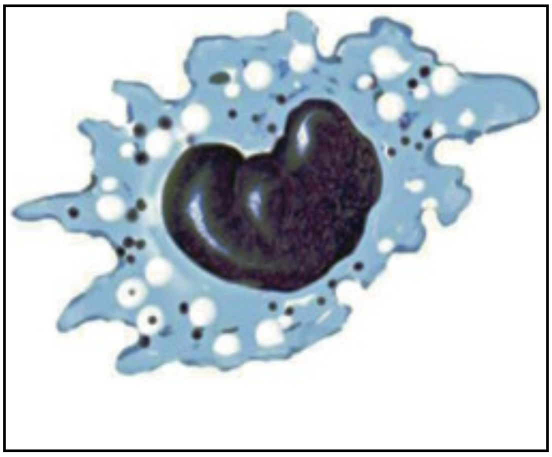


Fig. (10) Macrophage

Including two types:

1. The fixed macrophages:

They are large phagocyte cells, their types and names depend on the tissues where they exist. They are found in most body tissues and ready to engulf foreign particles as well as micro- organisms.

2. Mobile macrophages:

They offer information which are collected about microbes and foreign particles to the specialized immune cells found in lymph nodes scattered in different body parts.

Immune cells prepare suitable defense mechanisms such as antibodies and specific types of killer cells that deal with these microbes.

Fifthly: Assisting chemical substances:

These chemicals help and cooperate the specialized mechanisms of the immune system; they are many chemicals such as:

a) **Chemokines:** They recruit (guide migration) of large circulating phagocyte cells which are found in blood with large number to sites of existence of microbes or foreign particles to prevent their reproduction and spreading.

b) **Interleukins:** They mediate communication between different immune cells on one hand and between immune system and different body cells on the other hand, they help the immune system to perform its defense function.

c) **Complements:** Different types of proteins and enzymes that destroy microbes in blood after their conjugation with antibodies, they lyses the membranes of antigens and dissolve their content, which makes them easily engulfed by phagocytes.

d) **Interferons:** These are different types of proteins that are produced by cells of tissues infected by viruses. Interferons are not specific for certain virus, they bind

to healthy cells neighboring to the infected cells and induce them to produce enzymes that inhibit the action of replication enzymes of the virus, thus preventing the virus nucleic acids from reproduction and spreading in the body .

Sixthly: Anti- bodies:

Surface of bacteria cells that invade body tissues have compounds called antigens Receptors on the surface of B- lymphocytes recognize and join with antigens on the surface of bacterial cells or foreign bodies and produce antibodies.

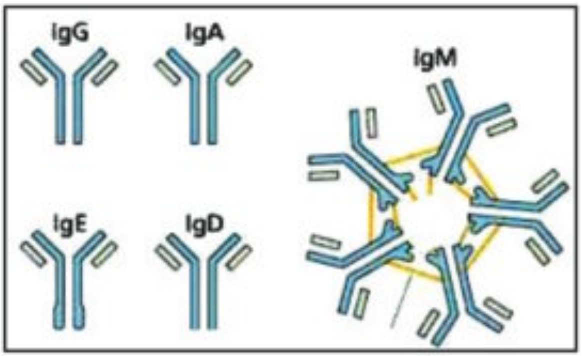


Fig. (11) Types of Anti-bodies

Antibodies are specific proteins known as immunoglobulin (Ig), they are five types IgG, IgM, IgD, IgE and IgA which circulate in blood and lymph.

Antibodies and complements adhere with bacteria cells to offer them to other white blood cells to engulf them , when B – lymphocytes join with antigens for the first time they divide many times to produce groups of cells , each group produce specific type of antibodies against specific type of antigen.

Thereby, B-Lymphocytes can invade the antigen on the surface of microorganisms and the other foreign molecules by producing antibodies which circulate with the blood and lymph.

Shape and structure of antibodies

Antibodies are proteins called immunoglobulins (Igs) that are Y- shaped and present in the blood, and lymph of human and the other vertebrates. They are produced by antibody-secreting plasma B- cells.

The antibody consists of two pairs of polypeptide chains, two of these chains are long and called heavy chains; the other two chains are short and called light chains. fig (12).

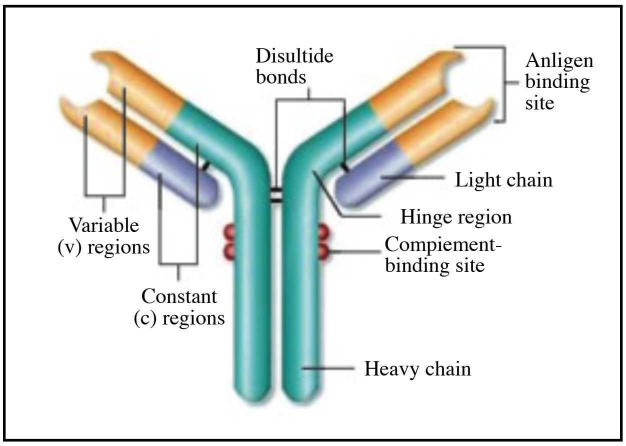


Fig. (12)

The four chains are joined together by disulphide bonds.

Each antibody has two identical antigen- binding sites; the shape of these sites is different from an antibody to another. The binding between an antigen and its specific antibody at these sites resembles the lock and its key. This binding forms an antigen-antibody complex.

The antigen- binding sites are located at the two tips of the Y- shaped molecule and is known as the variable regions (v) because the shape varies from antibody to another, while the rest of the antibody is known as the constant region (c) because it has a constant shape and structure in all types of antibodies.

The specificity of the antibody is determined by the conformation of amino acids (their sequence, types and spatial shape ……etc) at the antigen- binding site (the variable regions of the polypeptide chains), which is a mirror image of a specific antigen.

Mechanisms of antibodies:

Antibodies have only two antigen- binding sites, whereas as antigens have many binding sites, which makes a confirmative binding certain between the antibodies and their antigens. Antibodies stop the action of antigens by using one of the following mechanisms:

1. Neutralization

The most important function of antibodies in resisting viruses is neutralizing these viruses and stopping their activity. This is done when the antibodies bind to the outer coats of the viruses, this binding will prevent the viruses from adhering to the membranes of the host's cells and from spreading or pass to inside them. If the viruses succeeded in penetrating the host cell membrane, the antibodies will prevent the nucleic acid of the virus from coming out of the protein coat and replication inside the host cell by keeping the coat intact or sealed.

2. Agglutination (clumping)

Some antibodies, such as IgM has many antigen- binding sites, which enable each of them to bind to more than one microbe (antigen); this leads to the clumping of microbes on the same antibody, this makes them weaker and liable to be engulfed by phagocytes. fig (13).

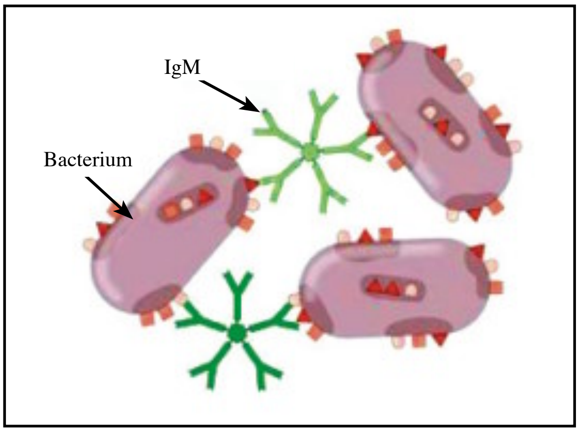


Fig. (13) Agglutination (clumping)

3. Precipitation

This happens usually in the soluble antigens, in which the binding between antibodies and these antigens leads to the formation of insoluble antigen- antibody complexes, which form a precipitate, to facilitate its engulfing by phagocytes. Fig (14).

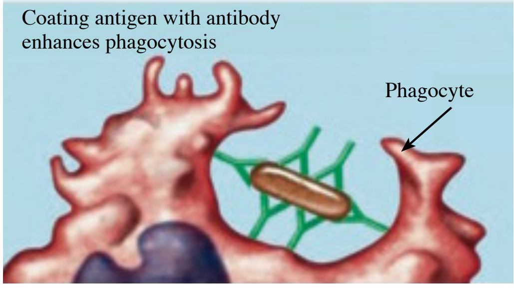


Fig. (14) The Precipitation

4. Lysis

The binding between antibodies and antigens activates specific proteins and enzymes called complements to lyse the coats of antigens and dissolve their content, which makes them easily engulfed by phagocytes.

5. Antitoxins

Antibodies can also bind to toxins and form complexes of antibodies and toxins. These complexes activate the complements to react with them in a chain reaction, which leads finally to detoxifying them and also makes them readily engulfed by phagocytes. Fig (15).

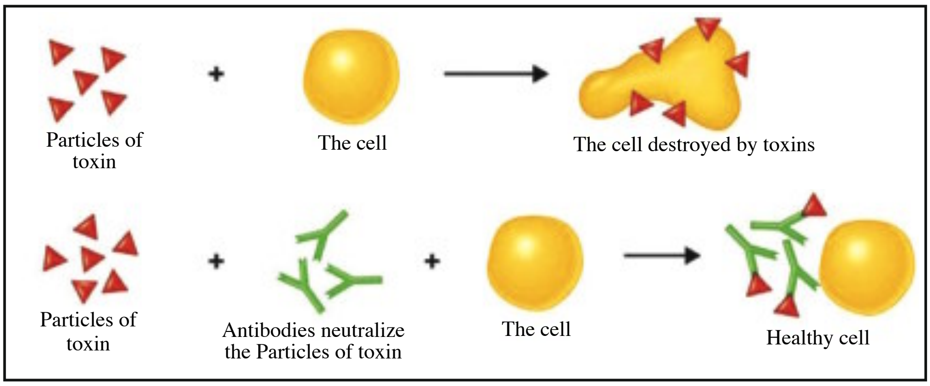


Fig. (15) Antitoxins

The Immune system mechanism in Man

How the human body protects itself from pathogen?

There are two systems of immunity in man:

1. Natural (non-specific or innate) immunity
2. Acquired (specific or adaptive) immunity:

Although the two systems of immunity are different, they work together in a cooperation and harmony, in which each of them uses different mechanisms that activate the immune response of the other system, i.e., they activate each other to help the body to deal successfully with pathogens.

First: Natural (non-specific or innate) immunity

This immunity is a group of defense mechanisms that protect the body and is characterized by rapid, effective response to resist, fight and destroy any microbe or foreign body that invades the body, these mechanisms are nonspecific against specific type of microbes or antigens and can be classified into two lines of defense, as follows:

1. **The first line of defense:** which includes a group of physical natural barriers in the body such as the skin, mucus, tears, sweat, and hydrochloric acid of the stomach. The main function of this line is preventing pathogens from entering the body.

   a) **The skin:** which is characterized by a tough horny layer on its surface, which acts as a barrier that difficult to be penetrated or to pass through. Also, the sweat, secreted by the sweat glands on the skin surface, can kill most of the microbes because of its salinity.

   b) **The Cerumen (ear's wax):** a substance secreted by the ears that can kill microbes, thus protecting the ears.

   c) **The Tears:** which protect the eye from microbes because it contains enzymes which lysis the microbes.

d) **The Mucus in the respiratory tracts:** which is a viscous fluid that lines the respiratory bronchi to adhere with the microbes, and foreign bodies, entering with air, then the mucus together with the trapped microbes is expelled to the outside of the body by the action of the beating cilia lining these tracts.

e) **The Saliva:** which contains substances that kill microbes, in addition to enzymes that can dissolve such microbes.

f) **The acidic gastric juice:** the epithelial lining of the stomach produces and secretes the strong hydrochloric acid that can kill microbes entering with food.

2. The second line of defense:

This system acts if pathogens succeeded in penetrating the first line of defense and invaded body tissues through a slash in the skin, for example. This line of defense is different from the first line in being internal one, in which the body uses successive nonspecific mechanisms that surround the invading microbes to prevent the microbes from spreading. These mechanisms start by a severe inflammation.

Inflammatory response: which is a nonspecific defense mechanism in the area of injury as a response to the damage of tissues caused by the injury or by the infection. Fig (16). Inflammation leads to some changes that takes place in the area of injury, where the blood vessels dilate to the maximum limit because of secreting large quantities of inflammation - generating substances, the most important one is the histamines, that are secreted by specific cells like mast cells and basophils. These substances increase the permeability of arterioles and capillaries to blood fluids which then leak from the blood circulation, leading to the swelling of tissues in the site of injury, and it also allows the passage of chemicals that kill and dissolve bacteria to the site of infection. The increase in the permeability of blood vessels also enables white blood cells as neutrophils, Monocytes and Macrophages to fight and kill foreign bodies and microbes.

In addition of interferons and the natural killer cells (NK) as components of the second line of defense.

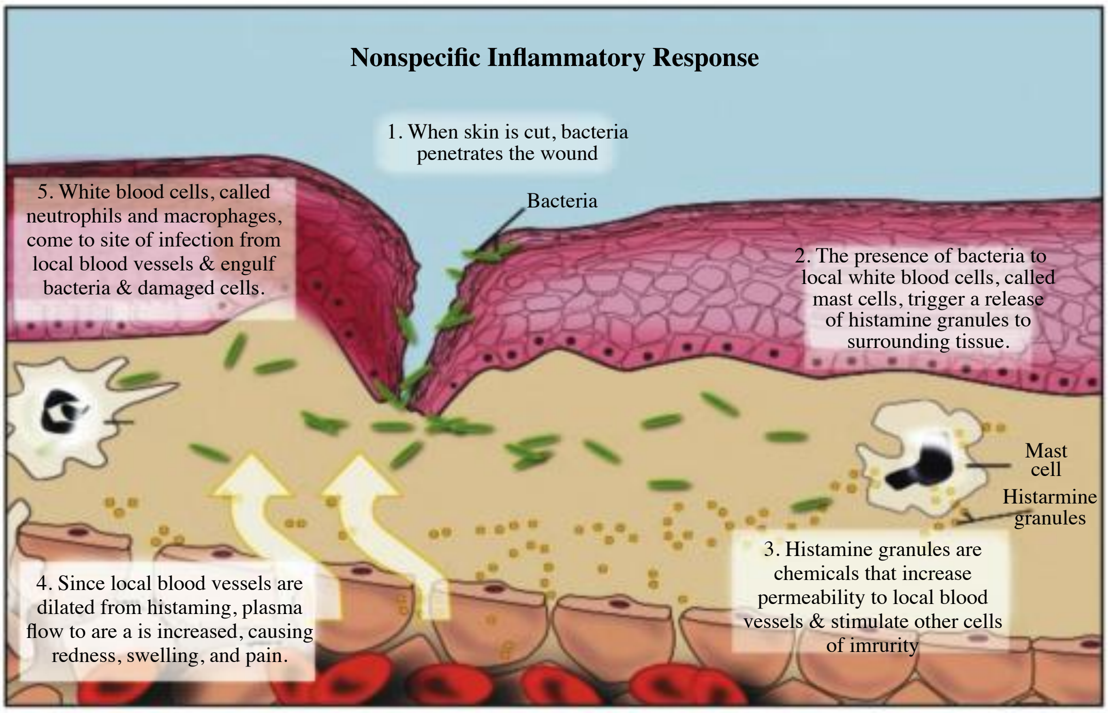


Fig. (16)

Second: Acquired (specific or adaptive) immunity:

If the second line of defense failed in getting rid of the foreign body, the body will use a third line of defense that includes lymphocytes that respond to this by a series of specific defense mechanisms that resist the pathogen. These defense mechanisms are collectively called the immune response. This acquired (specific) immunity is done through two separate mechanisms that are actually interconnected with each other. These two mechanisms are:

A) Humoral or antibody-mediated immunity:

This mechanism defends the body against antigens, pathogens (like bacteria, viruses, and toxins) present in the body fluids (blood plasma and lymph), by producing antibodies. This is done on the following steps: fig (17)

1. When a pathogen enters the body carrying on its surface a specific antigen, the

B- lymphocytes recognize this antigen (each B- lymphocyte is very specific and can respond to a single specific antigen only). When the B- lymphocyte recognizes its specific antigen, it attaches itself to the antigen by using the immune receptors present on the surface of the B-lymphocytes.The antigen binds with a protein in the B-lymphocytes and called major histocompatibility (MHC) .

2. At the same time, the macrophages engulf the antigen and digest it by its lysosomal enzymes into fragments, these fragments bind inside the macrophages to a protein called major histocompatibility complex (MHC), then the complex resulting from the binding between the antigen and the MHC transfers to the plasma membrane of the macrophage to be presented on its outer surface.

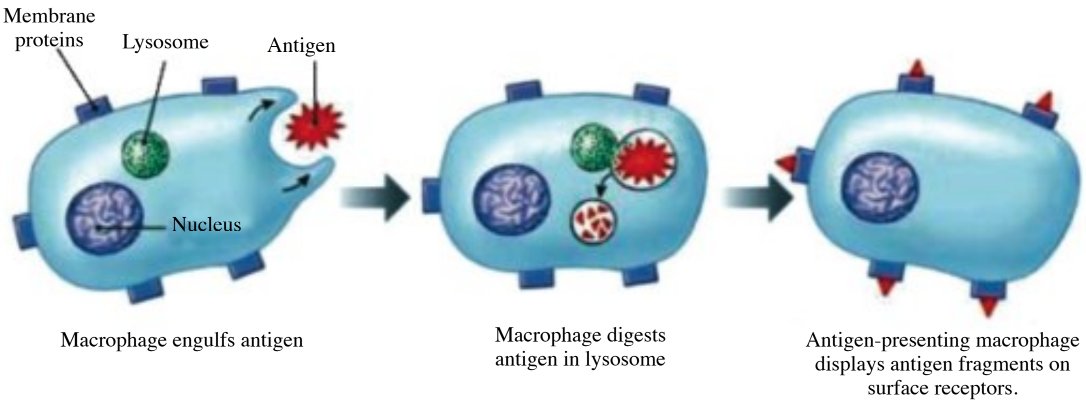


Fig. (17)

3. The T helper lymphocytes (T_H) will recognize the antigen by the MHC protein present on the surface of macrophages and bind to the antigen- MHC complex. Fig (18). This binding will activate the T_H to release interleukins, that will activate the B cells carrying on its surface the antigens bound to the MHC (N.B. The T_H can recognize antigen only after being treated by the macrophages and presenting it on its outer surface bound to the MHC).

4. The Activated B cells will divide, multiply and differentiate into memory cells and plasma cells, which produce large amounts of antibodies, which pass through lymph

vessels and blood circulation to fight the infection. Memory cells will remain in the blood for long periods (20-30 years) to recognize the same antigen if it re-entered the body, where they divide and differentiate into plasma cells that secrete antibodies specific for the same antigen making a rapid response (faster than the first response to the first infection).

5. The antibodies produced by the plasm cells will reach the blood circulation through the lymph, where they bind to the antigens found on the surface of the invading pathogens, this will activate the macrophages to re-engulf these antigens. This will continue for days or weeks (Fig. 18) .

   The antibodies produced by plasma cells are not effective enough to destroy foreign cells such as the cells infected by viruses because these antibodies are relatively large sized molecules that cannot reach the virus inside the cell. In this case the foreign bodies will be combated by the T lymphocytes.

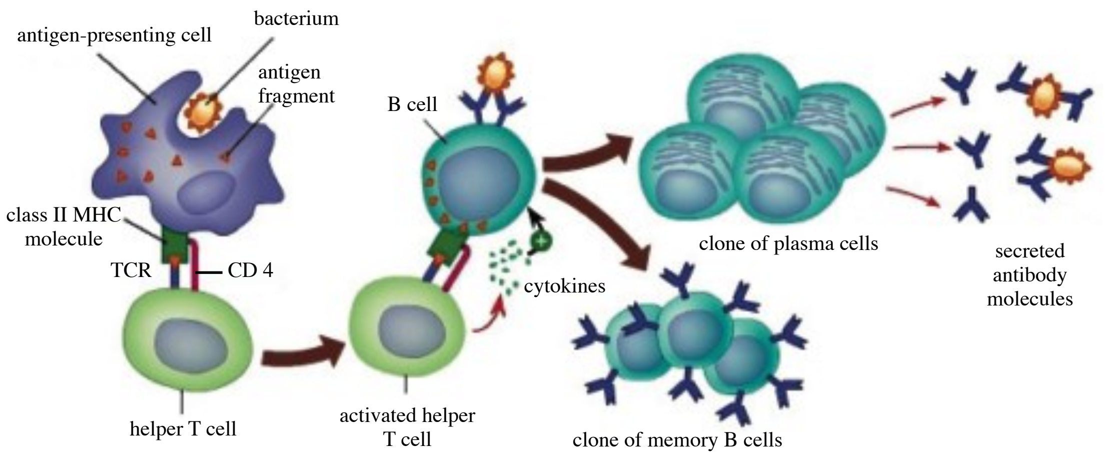


Fig. (18)

B) Cellular or cell-mediated immunity:

This is the immune response done by T lymphocytes, which is done by the receptors found on its membranes that give it a specific response to antigens. Each T cell can produce during its maturation a specific type of receptors specific to its membrane, each of these receptors can bind to a single type of antigens (presented by the macrophages).

This mechanism can be summarized as the following: Fig (19).

1. When the pathogen (bacteria or virus) enters the body, the macrophages will engulf it and decompose it into small fragments that bind inside the macrophage to MHC. The antigen- MHC complex will transfer to the plasma membrane of the cell to be presented on its outer surface.

2. The T helper lymphocytes (T_H) which has the receptor CD4 in its membrane will bind to the antigen-MHC complex presented on the surface of the macrophage, when its CD4 receptor binds to this complex. This binding will activate the (T_H) cells. The activated T_H cells will release interleukins to activate the (T_H) bound to the antigens to divide to form a strain of activated T_H cells and memory T_H cells, that last in the blood for long times to recognize the previous antigen if it entered the body again.

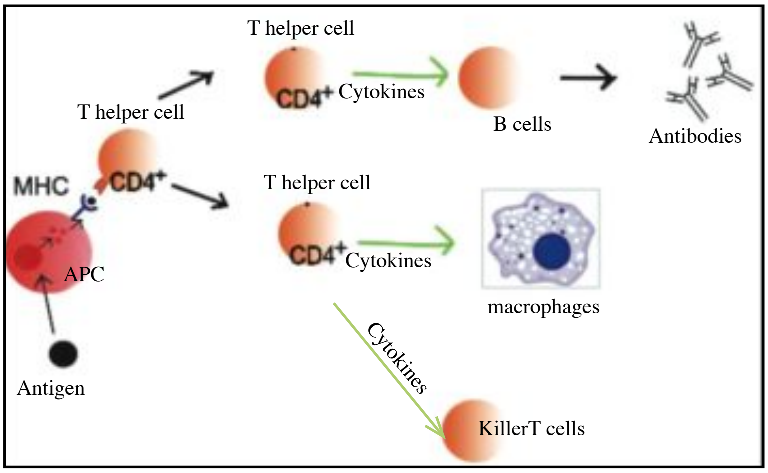


Fig. (19)

The activated T helper cells also secrete different types of the proteins cytokines that do the following:

a) Attract the macrophages to the site of infection in large amounts.

b) Stimulate the macrophages and other types of T lymphocytes (Tc) and B lymphocytes, therefore activating both cellular and humoral immunity.

c) Activating the natural killer cells to attack the abnormal body cells like cancer cells or cells infected by pathogens.

3. The cytotoxic T cells can recognize foreign bodies by the help of the receptor CD8 found in its surface, whether these foreign bodies are transplanted tissues or the antigens of the microbes that enter the body or cancer cells and destroy them. When these cells bind to the antigen, they create pores in the membrane of the foreign body (microbe or cancer cells) by secreting a specific protein called perforin (perforating protein), or by secreting lymphatic toxins that activates certain genes in the nucleus of the infected cell , leading to the destruction of the nucleus and its death.

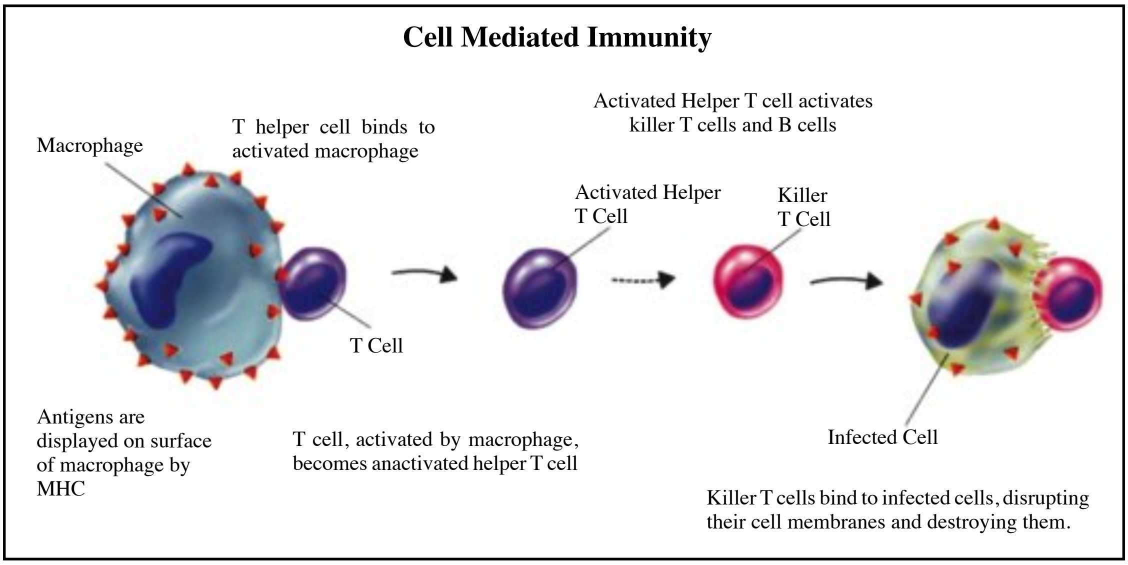


Fig. (20)

Inhibition of immune response:

After destroying the antigens, the T suppressor cells (Ts) bind, with the help of the receptor CD8 found in its surface, to plasma cells, T helper cells and T cytotoxic cells.

This binding will help it to secrete proteins called Lymphokines which suppress or inhibit the immune response or stop it, therefore, plasma cells will stop producing antibodies and many of the T helper cells and the activated T cytotoxic B-cells will die, but some of them will be stored in the lymphatic organs, where they stay ready to combat any similar infection when needed.

Stages of Acquired immunity

When somebody is infected with a specific disease like measles, he will not be infected again by the same disease along his lifetime,do you know why? because he gains acquired immunity against this disease and it passes through two stages:

The first stage: primary immune response

When the immune system encounters a new pathogen, The B and the T cells will respond to the antigens of this pathogen and attack it until it is destroyed, this takes a longer time since these cells need time to multiply, and this is why the first response takes between five to ten days to reach its maximum productivity of B and T cells. During this time, the infection could be widespread and the symptoms of the disease appear.

The second stage: Secondary immune response

If the same individual is infected by the same disease gain, the immune response will be very fast that the pathogen is destroyed before the appearance of the symptoms. The cells responsible for this secondary immune response are known as memory cells, which store information about the antigens fought by the immune system in the past.

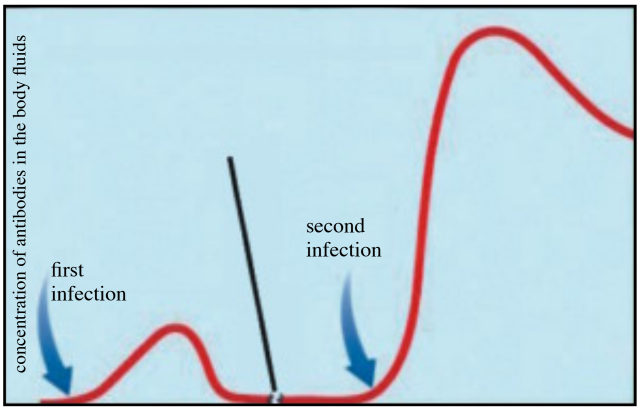


Fig. (21)

Your body contains both memory B cells and memory T cells, both types of memory cells is produced during the primary immune response. B and T cells can survive only for few day, but memory cells can live for Tens of years, and may survive till death.

During the second infection with the same pathogen, the memory cells respond to the pathogen once it enters the body, where they start dividing quickly to produce large amounts of the antibodies, and active T cells within short period of time.

Review Questions

First question: Choose the correct answer

1. From the biochemical means of immunity in plants is the …………… (cork formation- Phenol formation – gum deposition – Tylosis formation).

2. The lymphoid stem cells mature and differentiate into different types of T lymphocytes in the …………
   a) Bone marrow b) Thymus gland c) Spleen d)Tonsils

3. The B- lymphocytes are produced and matured in the …………
   (thymus gland- bone marrow- spleen- tonsils).
   a) Thymus gland b) Bone marrow c) Spleen d) Tonsils

4. The lymphocytes that found in the blood are ……….
   a) B-cells b) T- cells
   c) Natural killer cells d) All the previous

5. Lymphocytes which attack carcinogenic cells and transplanted organs are ………..
   a) helper T - cells b) Toxic T- cells
   c) suppressor T- cells d) All the previous

6. From the cells which have the ability to engulf the microbes and foreign bodies………
   a) macrophages b) Multinucleated white blood cells
   c) Single nucleated white blood cells d) All the previous

Question 2: Give reasons for:

- Thickening of the plant cell wall with cellulose and lignin
- Outgrowths extend from the parenchyma cells neighboring the tracheids and enter through their pits when the vascular system is cut or invaded by pathogens.
- Some plants secrete poisonous substances like phenols.

- Thymosin hormone plays an important role in the action of the immune system.
- The number of T- suppressor cells increase after destruction of the pathogen.
- The secretion of Interferons increases in cells infected with viruses.
- There are many types of antibodies.
- Tears and saliva are considered as a kinds of natural immunity.
- Human is infected only once with measles.
- Plants kill some of their infected tissues with microbes.

Question 3: What happens in each of the following cases?

1. The entry of a microbe with a specific antigen on its surface into the human body.
2. A part of the plant body is cut.
3. The plant is infected with poisonous bacteria.
4. The deficiency of thymosin hormone in the human body.
5. The deficiency of interferons in the cells the infected cells with viruses.

Question 4: Compare between:

1. Natural and acquired immunity in human.
2. Structural and biochemical immunity in plants.
3. B -lymphocytes and T -lymphocytes.
4. Cytotoxic T- cells and suppressor T- cells.
5. Chemokines (cytokines) and interleukins.
6. Complement system and interferons.
7. Primary and secondary immune responses.

Question 5: What is meant by:

1. Biochemical immunity in plants
2. Tyloses
3. Lymph nodes
4. T- lymphocytes
5. Macrophages

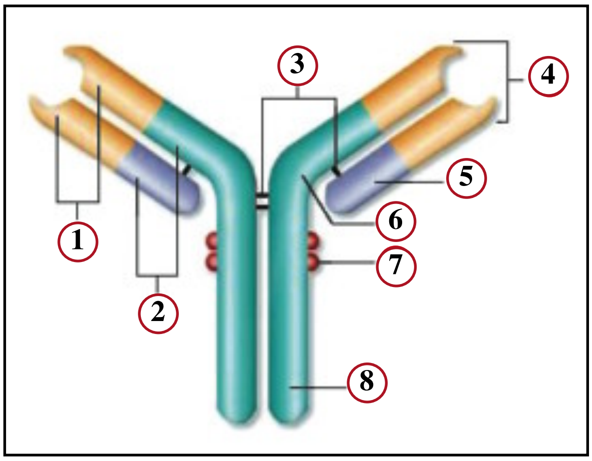
6. Chemokines.
7. Interferons
8. Complement system
9. Inflammatory response
10. cell- mediated immunity.

Question 6: state the site and the function of :

1. Thymus gland
2. Spleen
3. Tonsils
4. Peyer's patches
5. Natural killer cells
6. Cerumen

The opposite figure shows the structure of the antibody. Use the figure to answer the following questions:

1. Label the opposite figure.
2. What are the heavy chains and the light chains and how they bid to each other?
3. How antibodies differ from one to another?
4. What is meant by the constant and the variable regions of the antibody?
5. How antigen- antibody complex is formed?



Question 8: The inflammatory response is produced when a body cell is harmed

a) What is the role of histamine in the inflammatory response?

b) What is the benefit obtained from the involvement of different types of white blood cells in in the inflammatory response?

Question 9: Identify the role of memory cells in protecting the body from diseases.

Question 10: Mention some of the natural immunity mechanisms that represent the first line of body defense in man.

Question 11: Mention the morphological changes that take place in the plant cells after being infected by microbes..

Question 12: Mention three lymphatic organs that play an important role in the immune system in human, then explain the role of each organ in protecting the body.

Questions 13: explain by help of labeled diagram

a- T.s in a lymphatic node

b- the structure of antibody

Questions 14: Explain withdrawing the different types of white blood cells.

Question 15: Explain the different mechanisms of antibody action.

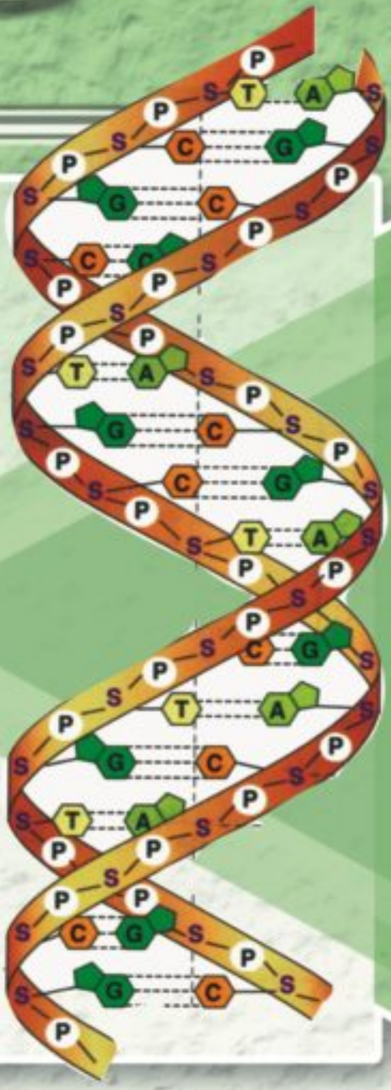
Question 16: Describe how lymphocytes identify pathogens and they bind to them?

Unit Two

Molecular Biology

Chapter One

DNA and Genetic Information



At the end of this chapter the student should be able to :

- Recognize the role of scientists in knowing the genetic material.
- Recognize the structure of the nucleic acid DNA.
- Recognize how DNA is replicated and the importance of this to the cells.
- Appreciate the role played by the scientists in elucidating the structure of the double helix of DNA and its replication.
- State the differences between DNA in prokaryotes and eukaryotes.
- Imagine the length of DNA and how it is condensed to occupy the small space of the nucleus.
- Recognize the genome.
- Know the mutation and its kinds.
- Discover the causes of mutations and their results.

DNA and Genetic Information

In the following we will address some fundamental questions of life: What directed the single fertilized egg, from which each of us originated to divide, and the resulting mass of cells to grow and take shape as a unique individual? What makes each of us distinct from other people, but gives us all a basic similarity as members of the human species? The answer to all such questions is genetic information. And the units of genetic information that govern the inherited characters are called genes. Biologists found that at cell division, the chromosomes in the nucleus separate from each other and at the end each cell contains the number of chromosomes found in the original cell. This convinced biologists that chromosomes were the bearers of genetic information. But, chromosomes are composed of two substances: DNA and proteins, but which of them carries the genetic information?

Obviously genes must contain a variety of information. It was known that proteins are a diverse and complex group of molecules. Proteins contain 20 different kinds of amino acid monomers in different combinations, whereas DNA contains only four kinds of nucleotide monomers. Thereforem scientists thought at first that proteins carried the genetic information, but in the 1940 this was shown to be wrong: DNA contains the genetic information. The discovery that DNA is the genetic material led scientists to study the molecular basis of inheritance, often called Molecular Biology, one of the most exciting and fast-growing fields of modern science.

Evidences that DNA is the Genetic Material

1. Bacterial Transformation

The first evidence to cast doubt on the belief that genes were made of proteins came in 1928 when the British scientist Griffith was studying bacterial pneumonia. He discovered that one strain of pneumonia bacteria could be transformed into a genetically different strain Fig (1).

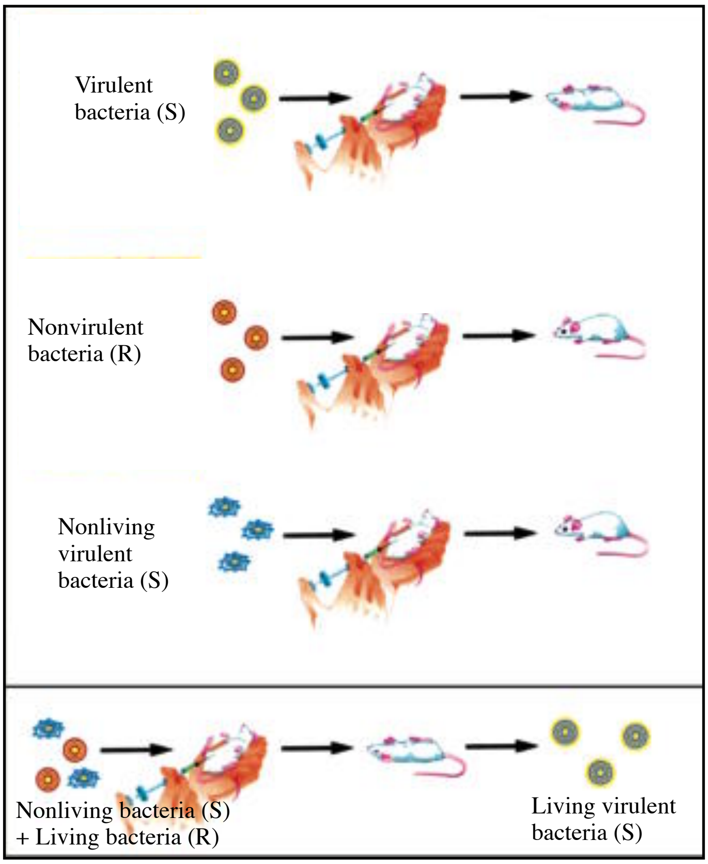


Fig. (1) Griffith's experiment

- One of the two strains he studied was virulent (S) type, that killed mice into which it had been injected.
- The other strain was nonvirulent and did not kill the mice (R) type. He made sure of

that.if virulent bacteria which have been killed by heating were injected into mice, the mice did not die.

When another group of mice were injected with non-living virulent bacteria (S) along with living non-virulent bacteria (R), some mice died and by examining the mice, he found that they contain living virulent bacteria(S). Griffith concluded that some of the genetic material from the virulent bacteria had entered the nonvirulent ones, transforming them to the virulent form. This phenomenon was named bacterial transformation, and he didnot explain how the genetic material transformed from (S) bacteria to (R) bacteria.

Avery and his colleagues isolated from the virulent bacteria a material that was capable of inducing genetic transformation in the nonvirulent bacteria. The chemical and physical analysis showed that this material is DNA.

The bacterial transformation experiment can be explained as follows: a strain of bacteria absorbed DNA of another strain by a method which is not known till now and gained the characteristics of the bacterial strain from which DNA came, and more important is that this bacterial transformation of recipient bacteria was transferred to the next generations.

Crucial experiment

Anobjection was carried out at fiast that DNA is genetic material. Some which based on that the DNA used was hot pure enough out was contaminated with protein, perhaps this protein was the transforming material. However, the crucial experiment was carried out when an enzyme capable of hydrolysing DNA completely was isolated. This enzyme which is called deoxyribonuclease hydrolyses DNA completely but it does not affect the proteins or RNA. It was found that when the transforming material was treated with this enzyme, transformation did not occur indicating that DNA is the genetic material.

2. Bacteriophages:

Another evidence that DNA is the genetic material came from studies of bacteriophages (phages for short). A virus particle consists of a molecule of DNA inside a protein coat. The phage used in these experiments was known to consist of a DNA molecule and a protein coat which extends to something like a tail which attaches to the bacterial cell

wall. It was observed that after 32 minutes of the attachment of the phage to the bacterial cell wall, the bacterial cell burst and comes out of it about 100 new complete phages. It is obvious then that some material (or group of materials) passed from the virus to the inside of the bacterial cell and caused the formation of new viruses. Thus, this material which entered to the inside of the bacterial cell must contain the virus genes.

It is known that DNA contains phosphorus in its structure whereas proteins do not and proteins contain sulphur in its structure whereas DNA does not. Hershy and Chase made use of this fact in carrying out an important experiment (Fig. 2). They labelled phage protein with radioactive sulphur and phage DNA with radioactive phosphorus they allow the phage to attack bacteria and they detect the radio active phosphrons and radioactive sulphur inside and outside the bacterial cells.

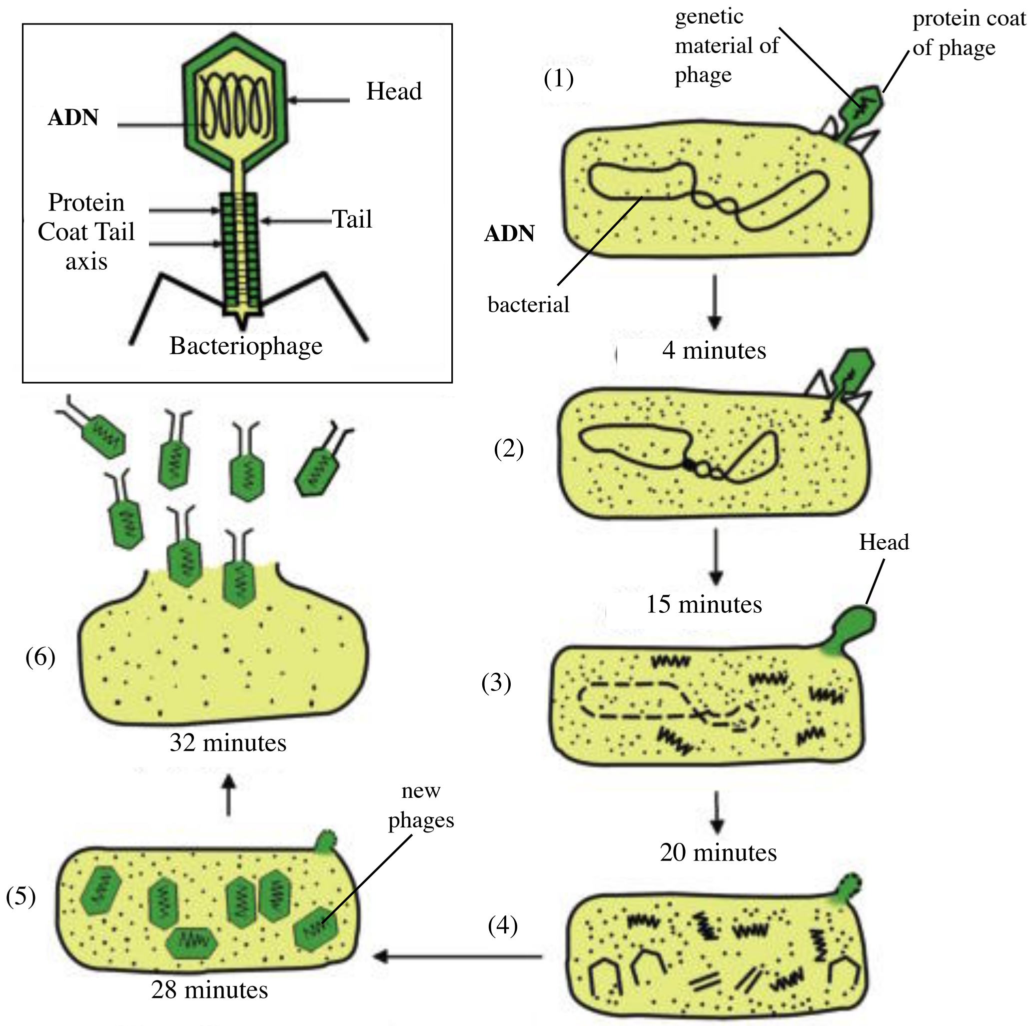


Fig. (2) Infection of a bacterium by a bacteriophage

The results of this experiment showed that all viral DNA almost enter to inside the bacterial cell, where as viral protein did not enter to inside the bacteria except less than 3%, which mean that DNA entered to the bacterial cell and push it to build new viruses).

The conclusion from bacterial transformation experiments and the experiments on the phage is that the genes, at least those of pneumonia bacteria and the phage are composed of DNA.

Note that we restricted this conclusion to the living organisms on which the experiments were carried out and the following question is:

Are all genes composed of DNA? The answer to this question is no, because there are some viruses which do not contain DNA in their structure, but contain RNA and it was proven that the genetic material in these viruses is RNA. But these viruses are exceptions to the rule as they form a small part of the forms of life. And in view of the various studies that were carried out till now it is confirmed that DNA is the genetic material in nearly all the forms of life.

3. The quantaty of DNA in cells:

There is another evidence that DNA is the genetic material in eukaryotis came from measuring the quantity of DNA in different kinds of somatic cells of a certain living orgamism as (chicken) it was found that they are equal, but when the amount of proteins in the same cells was measured it was unequal.

And by comparing DNA in somatic cells and in reproductive cells (gametes) of the same living organism, it was found that the quantity of DNA in reproductive cells (gametes) equal half the amount of DNA in somatic cell. Since the new indvidual results from combination of male gamete and female gamete, so each gamete must contain half the genetic informations found in somatic cell or the genetic material will be doublicated in each generation while this not agree with protein which prove that protein not work as agenetic material.

On the other hand, proteins are continously being made and destroyed inside the cells, but DNA once made, is remarkably stable.

The Structure of DNA

By the early 1950's there was strong evidence that DNA carries a cell's genetic information of the cell and many people were trying to work out the structure of the DNA molecule and make a model of it. Any model of DNA structure must take into consideration the following in formations which came out from many experiments:

1. DNA is made up of nucleotides, a nucleotide is made up of three parts: a five - carbon sugar (deoxyribose in the case of nucleotides in DNA), phosphate group connected with convalent bond to the sugar's fifth carbon atom and one of four possible nitrogen containing bases connected with covalent bond to the sugar's first carbon atom. The nitrogen base may be one of the single-ring pyrimidine derivatives thymine (T) or cytosine (C) or one of the double ring purine derivatives adenine (A) or guanine (G).

2. When the nucleotides are linked together in a strand of DNA, the phosphate group attached to the 5 (pronounced "five prime") carbon of the deoxyribose sugar of one nucleotide becomes joined to the 3 carbon on the sugar of an adjacent nucleotide. (Fig.3) the strand in which the sugar alternate with phosphate is called sugar phosphate back bone. The backbone is not symmetrical. It has a definite orientation, with a free 3` hydroxyl group at one end and a free 5` phosphate group at the other end. The purine and pyrimidine bases stick out to one side of the sugar - phosphate backbone.

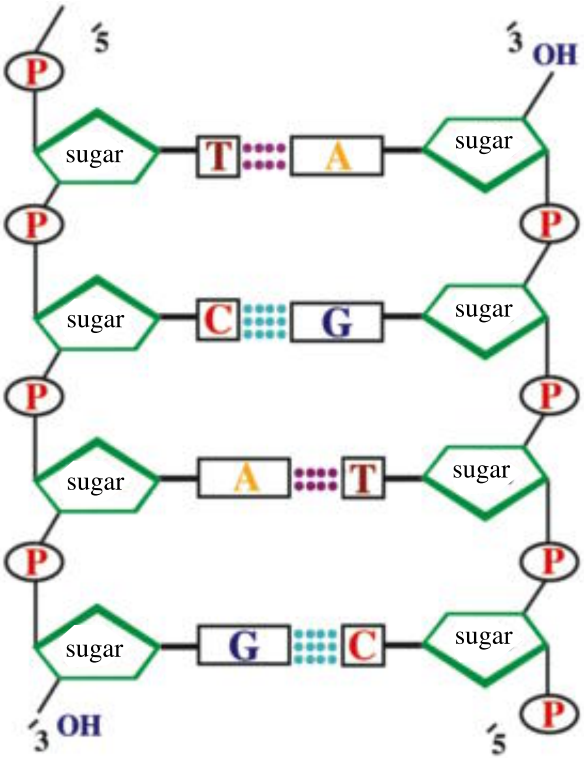


Fig. (3) The structure of DNA

3. In each DNA molecule, the number of nucleotides containing adenine (A) equals the

number containing thymine (T) and the number containing guanine (G) equals the number containing cytosine (C). That is A = T, and G = C.

4. The direct evidence of the DNA structure from studies made by Franklin where she used X-rays diffraction technology to get pictures of highly purified DNA crystals. In this technology X-ras pass through crystals of molecules which have regular structure and result from it a scattaring of X-rays. This produce a pattern of dots that its analysis gives information about the shape of the molecule. In 1952, Franklin produced such photographs for crystals of highly purified DNA. Her results showed that DNA is twisted into a spiral or helix, with the bases perpendicular to the length of the fibre. These pictures also provided evidence that the sugar-phosphate backbone is on the outside of the helix with the bases on the inside. Furthermore, the diameter of the helix showed that it must be composed of more than one strand of DNA.

After Franklin made her pictures a race started between scientists to put all the available data together into a consistent model of DNA structure. But the two British scientists Watson and Crick were the first to put an acceptable model. The model of DNA structure put by them consists of two strands of DNA. The two strands are arranged like a ladder, with the ladder's sides being the sugar-phosphate backbones of the two strands and the rungs being the bases. (Fig. 4).

A rung may consist of either an adenine paired to a thymine, or a guanine paired to a cytosine. In each rung, either base may be on either strand. The pair of bases in each rung is held together by hydrogen bonds. Two hydrogen bonds hold an adenine thymine pair together, while a guanine cytosine hold together by three hydrogen bonds.

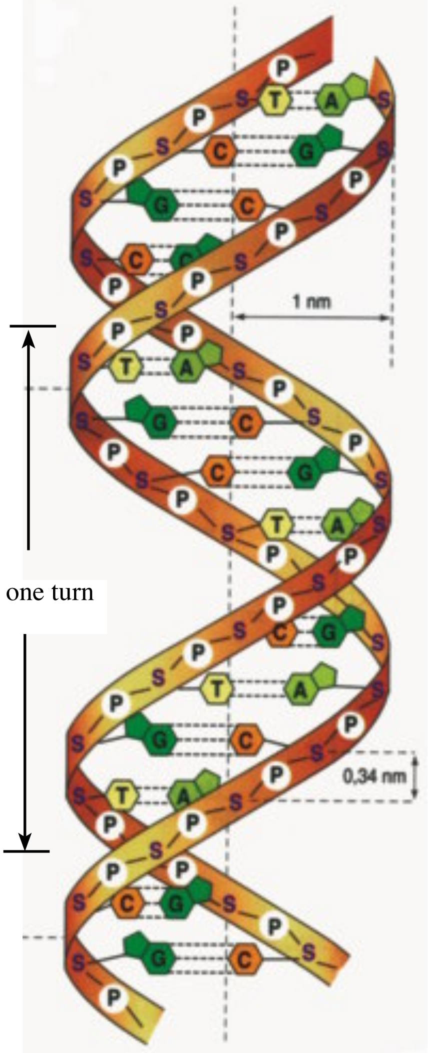


Fig. (4) DNA double helix

And since each pair consists of one single and one doublering, all the rungs of the ladder are the same width, and the backbones of the two DNA strands are always the same distance from one another along the length of DNA molecule.

Watson and Crick also saw that for hydrogen bonds to form properly between the base pairs in DNA, the two nucleotide strands of the DNA molecule had to run in opposite directions with the free 5`phosphate groups of the two strands at opposite ends of the molecule (Fig. 3).

Finally, the whole ladder of DNA is twisted, with ten nucleotide pairs per turn, to form the spiral detected by Franklin's x-ray photographs. Because the spiral is composed of two strands wound around each other, the DNA molecule is referred to as a double helix (Fig. 4).

DNA Replication:

Before a cell divides, its DNA is replicated (or duplicated), so that each new cell receives a complete copy of the original cell's genetic information. Watson and Crick pointed out that the double-stranded, base-paired structure of the DNA molecule incorporates a means whereby the genetic information can be replicated accurately. Because the two strands have complementary base pairs, the nucleotide sequence of each strand automatically supplies the information needed to produce its partner (for example, if a portion of one strand runs 5`A - A - T - C - C 3`, its partner must run

3`T - T - A - G - G 5`). If the two strands of a DNA molecule are separated, each can be used as a mold or template, to produce a complementary strand. Scientists proved that this is the case after carrying out several experiments.

Enzymes and DNA Replication

The replication of DNA demands the integrated action of a number of enzymes and proteins. For replication to occur, the following must happen:

1. The double helix must be unwound.
2. DNA - helicase enzymes move along the double helix, separating the two strands from each other by breaking the hydrogen bonds between the paired bases to expose the bases so that they can form hydrogen-bonds to new nucleotide partners.
3. DNA - polymerase enzymes build the new DNA strands which catalyze the addition of monomers, one by one, to the 3` end of the new DNA strand. To be added to the new strand, a monomer must be paired to a base exposed on the opposite, template DNA strand (Fig. 5).

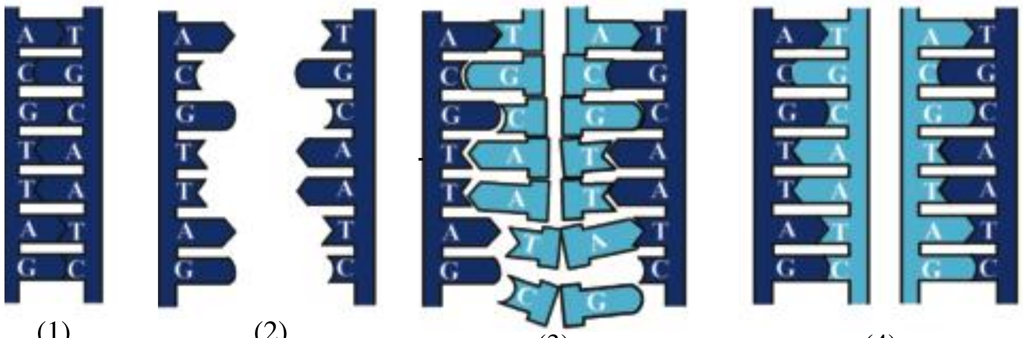


Fig. (5) DNA replication

It is known that DNA polymerase can work only in one direction from the 5` toward the 3`and on the new strand it is synthesizing, and we have said before that the two strands of the DNA double helix are antiparallel, that is one runs in the 5`to the 3`direction whereas its partner runs in the opposite, 3`to 5`. Therefore, as a helicase moves along, separating the two strands, it works towards the 3`ed of one strand and the 5`end of the other. For the 3`to 5`template strand, there is no difficulty, a polymerase follows the helicase, adding new nucleotides to the 3`end. However, this would not work on

the opposite strand because DNA polymerase cannot work from the 3`end toward the 5`end of the strand which is synthesizing. This strand has to be made in short pieces in the direction 5`to 3`, and these short pieces are soon joined together by another enzyme, DNA-ligase. (Fig. 6).

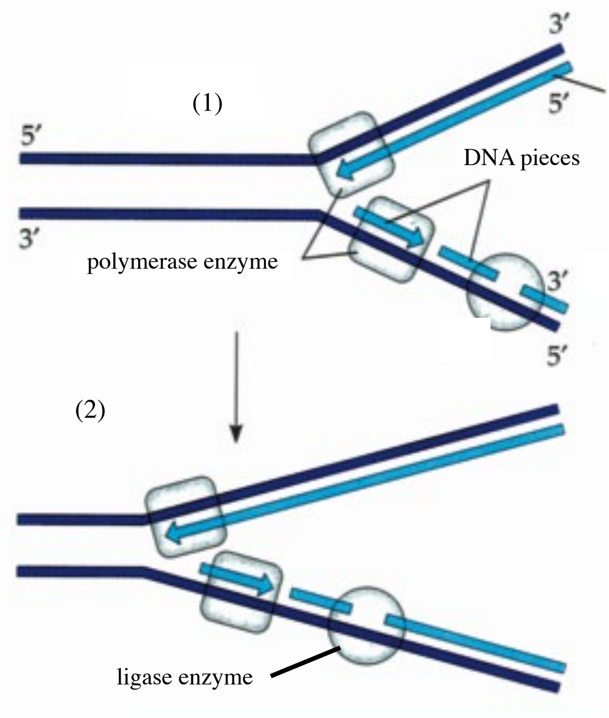


Fig. (6) Duplication of DNA

The DNA of eukaryotes is organized into several chromosomes. Each chromosome contains a single DNA molecule which runs from one end of the chromosome to the other, and replication starts at many different points along the molecule.

In a prokaryote, the DNA exists as a double helix with its ends joined to form a circle. The molecule is attached to the plasma membrane at one point. This point is where replication occurs.

DNA Repair

All biological polymers (long molecules formed of repeating units such as starch, protein and nucleic acid) are subject to damage from the body's own heat and from the aqueous environment inside the cell, and DNA is no exception. It was estimated that 5000 purine bases (A) and (G) are lost each day from the DNA of each human cell because heat breaks the covalent bonds linking them to deoxyribose. In addition, DNA can be damaged by various chemical compounds and radiation. Any form of damage to the DNA could alter its information content and produce disastrous changes in the cells proteins.

Although thousands of changes occur in a DNA molecule every day, no more than two or three stable changes accumulate in a cells DNA each year. The vast majority of changes are eliminated with remarkable efficiency by a group of 20 different kinds of DNA repair enzymes.

These enzymes which are called DNA-ligases, working in harmony can recognize and remove a damaged area of DNA and repairit where replacing it with nucleotides complementary to those on the strand opposite the damaged portion.

DNA repair depends on the existence of two copies of the genetic information, one in each strand of the double helix. As long as one of these strands remains undamaged, the repair enzymes can use it as a template to replace a damaged segment in its partner. Thus, most damage is remedied unless both strands are altered at the same location and the same time. The genetic material of some viruses occurs in the form of single stranded RNA, which cannot be repaired. These viruses show high rates of genetic change resulting from damage to their RNA. The double helix is, therefore, vital to the genetic stability of organisms that contain it.

DNA in prokaryotes

The genetic material of prokaryote is one double helix of DNA with its ends joined to each other to form a circle.

If the DNA of the bacterium *(Escherichia coli)* were stretched out in a straight line, it would be about 1.4 millimeter long, whereas the cell itself is only about 2 micron long. The circular bacterial DNA is folded many times, and occupies a nuclear area about one tenth of the cell's volume. This DNA molecule is attached to plasma membrane at one or more points (Fig. 7).

In addition, some bacteria also contain one or several additional, much smaller, circular DNA molecules called plasmids. Plasmids are widely used in genetic engineering as will be discussed later. A bacterial cell replicates any plasmids it contains at the same time as its main DNA replicate scientists take advantage of this activity by introducing artificial plasmids into bacteria in order to obtain several copies of them.

Fig. (7) Electron micrograph showing DNA in prokaryotes

The DNA molecules of mitochondria and chloroplasts (organelles of eukaryotic cells) is very similar to that of prokaryote. The DNA of these organelles and the yeast plasmids are all circular and not complexed with proteins that are always found with eukaryotic DNA.

Structure of Eukaryotic Chromosomes

Chromosomes appear in eukaryotic cells during cell division. Each chromosome is thought to contain a single DNA molecule extending from one end of the chromosome to the other, but coiled and folded many times. The DNA is associated with various proteins, forming what is called chromatin which contains roughly equal amounts of DNA and protein. The chromosomal proteins may be divided into histone and nonhistone proteins.

Histones make up a well-defined group of structural proteins. Histones are all small, and they have a high content of the basic amino acids arginine and lysine. At the pH inside the cell, these amino acids have positively charged R groups, and so they bind strongly to the negatively charged phosphate groups of DNA. Histones occur in enormous amounts in the chromatin of any cell. The nonhistone proteins are a heterogeneous group with many functions. They include some structural proteins, which play a role in the spatial organization of the DNA within the nucleus, and also include the regulatory proteins, which determine whether or not the DNA code is used to make RNA, proteins and enzymes.

The human somatic cell contains 46 chromosomes. If we imagine that DNA double helices from these chromosomes were lined up and stretched out, they would be about 2 meters long. The histone and other proteins are responsible for packing these long molecules into a nucleus 2-3 micrometer in diameter. Biochemical analysis and electron micrographs have shown that the DNA is wound around clusters of histones, forming a string of particles called nucleosomes (Fig. 8). This shortens the molecule about tenfold, but it must be packed about 100,000 times more tightly to fit into the nucleus. The string of nucleosomes is coiled so as to pack the nucleosomes together. However, even this is not sufficient to shorten a DNA molecule to the length actually observed. The tightly coiled strings of nucleosomes are arranged in large loops, believed to be held in place by structural nonhistone proteins of the chromatin. Chromatin packed up as tightly as possible is said to be condensed. When the DNA is in this state, enzymes apparently cannot get at it. The package must be unwound at least into a string of nucleosomes, before the DNA can serve as a template for DNA or RNA synthesis.

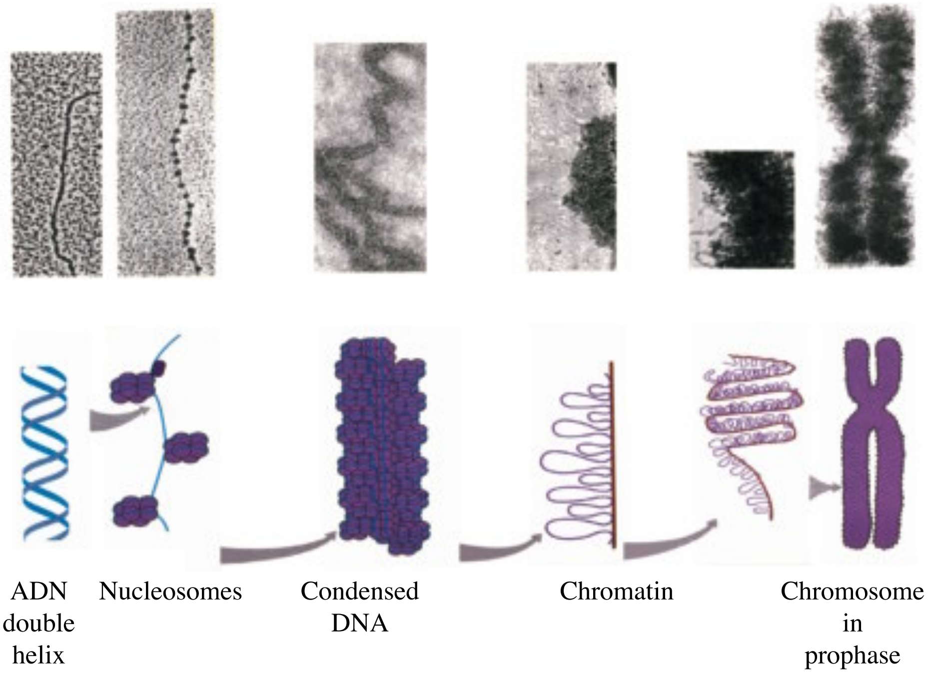


Fig. (8) The way in which DNA is packed in chromatin

Structure of the Genome

An individual's genome consists of the total of all the genes (and, therefore, of all the DNA) in any one of its body cells.

In 1977, researchers found methods of determining the sequence of nucleotides in DNA and RNA molecules. This provided the tools to describe precisely how genes are arranged within a cell's DNA molecule.

We have already met some parts of the genome. Many genes carry instructions for making proteins. Others dictate the sequence of nucleotides in the ribosomal RNA which enter in building of ribosomes and in transfer RNA, which carries amino acids during protein synthesis. In prokaryotes, genes dictating RNA and protein synthesis make up most of the genome. However, in many eukaryotes less than 70% of the genome serves these functions and the rest of the genome is unaccounted for. Researchers have identified and named various kinds of noncoding DNA (DNA that dose not code for RNA or proteins), but we still have much to learn about their function.

Repetitive DNA

Most genes are present in only one or a few copies in a genome. However every eukaryotic cell carries many - often hundreds - of copies of the genes needed to synthesize ribosomal RNA and histones. These are molecules the cell needs in large amounts, and it is reasonable to suppose that having multiple copies of these genes speeds up cells production of new ribosomes and histones.

DNA sequencing has turned up many more repeating sequences of DNA. The role of most of this repetitive DNA is still unclear. For instance, in the fruit fly Drosophila, the brief nucleotide sequence A - G - A - A - G is repeated about 100,000 times in the middle of one chromosome. These and many other repeated sequences are noncoding DNA.

Other Noncoding DNA

In addition to satellite DNA, eukaryotic genomes contain great deal of other noncoding DNA. Even befor DNA sequencing became possible, geneticists observed that the amount of DNA in species' genome bears little relationship to the complexity of the organism or the number of proteins it produces. Remarkably little of the DNA of the plants and animals actually codes for proteins. For example, the largest known genome belongs to a salamander; its cells contain about 30 times the amount of DNA found in human cells, although they produce fewer proteins.

Perhaps some of non coding DA act on keeping chromosomes structure, as shown that some regions of DNA are references to places at which the mRNA synthesis should start. These regions are importaint in synthesis of proteins.

Mutations

Mutation can be defined as a sudden change in the nature of the hereditary factors controlling certain traits which leads to change in these traits in the living organism. The mutation is considered true if it is transferred through different generations. We have to distinguish between the mutation which results from changes in the structure of the hereditary factor and the changes which result from environmental effects, or from segregation and recombination of genes. Most mutations lead to undesirable traits such as some deformations in man. Mutations in plants may lead to their sterility causing a deficiency in crop yield of these plants.

In rare cases, mutation leads to some desirable changes; and man tries all possible scientific ways to induce them artificially. For example, an American farmer discovered in his sheep one with short curved legs. He considered this a desired trait as it could not climb over fences and damage cultivated plants. The farmer took care of breeding this mutant sheep until it gave rise to a new strain known as the Ancon strain. Other examples of desirable mutations are those induced by man in crop plants in order to increase their yield.

Kinds of Mutations

Mutations are divided into two main kinds: gene mutations and chromosomal mutations.

1. Gene mutations:

These are due to chemical changes in the gene structure, mainly in the arrangement of the nitrogen containing bases of the DNA molecule. These changes finally lead to the production of a different protein which would in turn develop a new trait. Such change in the chemical structure of the gene is often accompanied by a change from dominant to recessive state, although the opposite may occur in some rare cases.

2. Chromosomal mutations:

These mutations occur by two ways:

a) Change in the number of chromosomes:

This means a loss or gain of one or more chromosomes during gamete production in the process of meiosis as in Klinefelter and Turner syndromes in man. The cells contain one or more extra chromosomes as in the first case or the cells may contain one chromosome less as in the second syndrome. The number of chromosomes may be duplicated in a cell due to the non-separation of the chromatids after centromere divison and failure of membrane formation between the two daughter cells, thus causing polyploidy. This phenomenon of polyploidy may take place in any living organism, yet it is more common in plants, where a large proportion of known plants have polyploidy (3N, 4N, 6N, 8N up to 16N), where chromosomes are duplicated during gamete formation. This results in the production of individuals with new characteristics. This is because each gene is represented by many copies, thus its effect becomes more pronounced. Thus the plant becomes taller and consequently, its organs become bigger especially flowers and fruits. Nowadays, there are many tetraploid (4N) crops and fruits such as cotton, wheat, apple, grapes, pears, strawberries and others.

Polyploidy is less common among a animals. This is because sex determination in animals demands delicate balance between the numbers of autosomes and sex chromosomes. Thus polyploidy in animals is restricted to some hermaphrodite snails and worms where sex determination problem does not exist. Triploidy in man was found to be lethal and cause miscarriage. However, polyploidy may occur in some liver and pancreas cells in man.

b) Change in the structure of the chromosome:

The sequence of genes on a chromosome changes when a piece is separated from it during cell division and rotates 180° around itself and rejoin the same chromosome again in an inverted position. It is also possible that two nonhomologous chromosomes exchange segments. In another case, a small segment of a chromosome may be lost or gained.

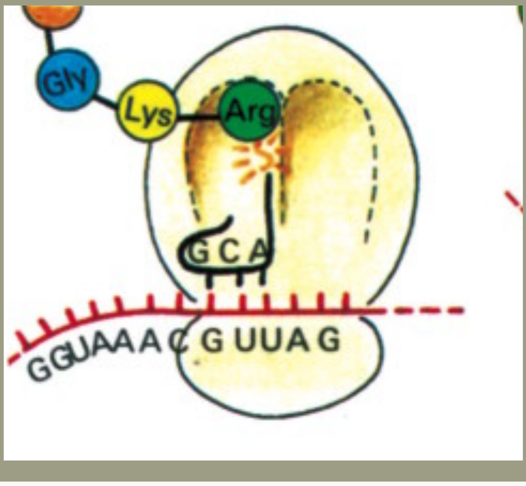
If the above mentioned mutations occurred in reproductive cells, the new trait will appear in the resulting embryo. This kind of mutation is then called gamete mutation, and it occurs in living organisms that reproduce sexually. Mutation may also occur in somatic cells where sudden appearance of symptoms occur in the organ whose cells mutated. This sort of mutation is known as somatic mutation. It is more common in plants that are propagated vegetatively, where a new branch may grow from the normal plant having a new trait. This branch may be cut off and propagated vegetatively if the trait is desirable.

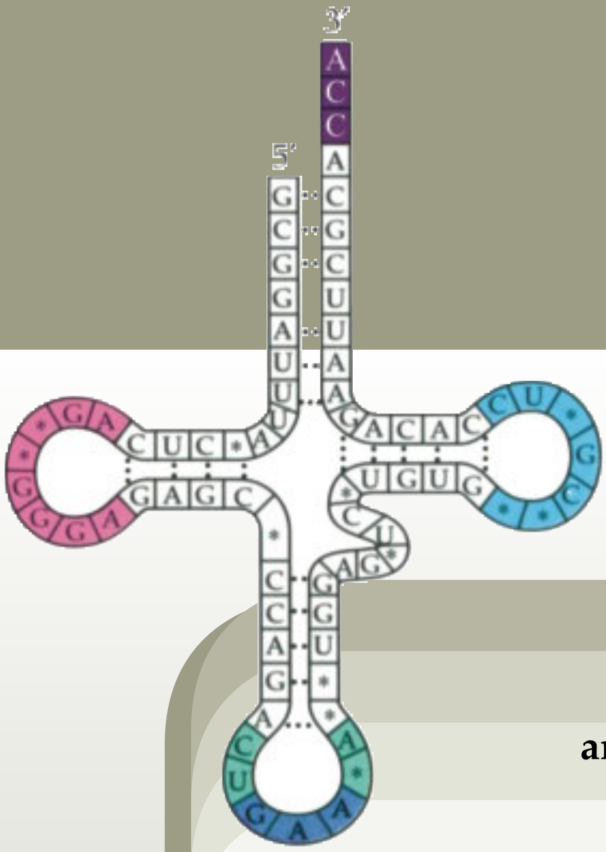
Origin of Mutations:

Mutations may be spontaneous or induced. The spontaneous mutation originates by itself without any human interference, and it is rare in all organisms. It is due to the effect of certain environmental factors around the living organism, such as ultraviolet and cosmic rays in addition to different chemical compounds to which the living organism is exposed. Spontaneous mutations play an important role in the evolution of the living organisms.

Induced mutations are those mutations which are induced by man to produce desired changes in the traits of specific organisms. For this purpose, man uses some factors that are found in nature such as gamma and ultraviolet rays. He may also use some chemicals, such as mustard gas, colchicine, nitrous acid and others. Such treatments cause atrophy and death of the growing tip cells in plants. New tissues are regenerated underneath the dead cells. These new tissues contain some polyploid cells.

Most induced mutations produce undesirable traits, yet man selects from them the useful ones. For example, some useful mutations may produce fruit trees with high sweet and seedless fruits. It was also possible to induce mutations in micro organisms such as penicillium which is capable of producing large quantities of antibiotics.





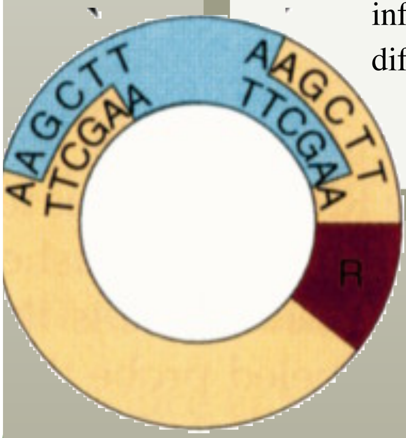
Molecular Biology

Chapter Two

Nucleic Acids and Protein Synthesis

At the end of this chapter the student should be able to :

- Know the kinds of proteins.
- know the structure of the nucleic acid RNA.
- Compare between these kinds of RNA (ribosomal - transfer - messenger).
- Know the genetic code.
- Know the steps of protein synthesis.
- Know the modern techniques of molecular technology.
- Know the concept of the human genome and its importance in drug manufacture.
- Appreciate the greatness of God concerning the genetic information and its role in characterising humans with traits that differ from one person to another.



Structure and synthesis of proteins

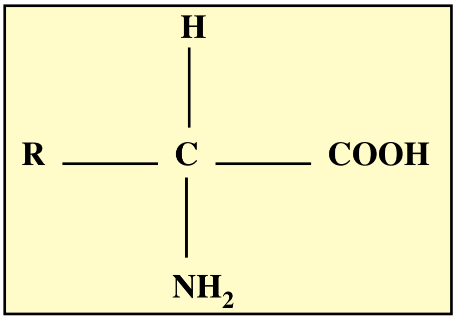
The enormous variety of proteins in living systems can be divided into two main groups:

1. Structural proteins:

These are proteins that constitute building materials in the living organisms. Major types of fibrous proteins that act as structural elements include actin and myosin of muscles and other contractile systems, collagens that form connective ligaments within the body, keratins that form protective coverings such as skin, hair, hooves, horns, feathers and others.

2. Regulatory Proteins:

These are the proteins that regulate the numerous processes and activities for the organism. These include enzymes that modulate chemical reactions, antibodies that provide immunity against infection, hormones and various other substances that make each life form respond appropriately to the constantly changing internal and external environments.



An amino acid

There is a common plan of construction for the thousands of kinds of proteins in living systems. The twenty kinds of naturally - occurring amino acid monomers are joined together in unbranched, linear polymer chains of proteins. All 20 amino acids have the same basic structure. There is a carboxyl group COOH and an amino group - NH_2 joined to the first or α-carbon atom and a hydrogen atom as a third unit bonded to this carbon in all amino acids.

Except for glycine, which has a second hydrogen atom joined to the α-carbon, the other 19 amino acids have a fourth group (R) which differs from one amino acid to the other.

In the presence of the appropriate enzymes, amino acids are joined together in a dehydration reaction by peptide bonds forming polypeptide polymers which form the protein. The differences between different proteins are due to the differences in the numbers, kind and arrangement of amino acids in polymers. It is also attributed to the number of polymers that form the protein, beside the weak hydrogen bonds that may give the protein molecule its special shape. Protein synthesis is very complicated process and it includes the interaction of different kinds of molecules.

Ribonucleic acids (RNAs)

Like DNA, RNA comes in long unbranched macromolecules made up of nucleotide subunits. Each nucleotide is made up of a sugar molecule, a nitrogenous base and a phosphate group. A nucleotide phosphate group is bonded to the third carbon of the sugar in the previous nucleotide to form the sugar-phosphate backbone of a nucleic acid. RNA, however, differs from DNA in several aspects:

1. The sugar in the RNA is ribose, whereas the suger in DNA is deoxyribose, which contains one less oxygen atom than ribose, hence the names ribonucleic acid and doxyribnucleic acid.
2. RNA usually consists of a single strand of nucleotides, although it can form double - stranded sections, DNA is usually double-stranded, consisting of two complementary chains of nucleotides.
3. DNA and RNA differ in the kinds of nitrogenous bases they contain. In DNA we find adenine, guanine, cytosine and thymine. RNA also contains adenine, guanine and cytosine, but uracil is present instead of thymine. Like thymine, uracil base-pairs with adenine.

Three main types of RNA participate in protein synthesis, these are:

1. Messenger RNA (mRNA):

The transcription of DNA into RNA begins when the enzyme RNA polymerase binds to a sequence of nucleotides on the DNA called the promoter. Next, the two strands of DNA are separated, and one strand serves as a template for the formation of

a complementary strand of RNA. RNA polymerase moves along the DNA and joins the complementary nucleotides to the growing RNA strand one by one. The enzyme works only in the 3`to the 5`direction on its DNA template, assembling RNA in the 5`to 3`direction. This process is much like the replication of DNA with one important difference. Whereas DNA replication, once begun, usually copies all the DNA in the cell, RNA synthesis transcribes only selected portions of the DNA.

Since DNA molecules are double-stranded, any section of DNA could, in principle, be transcribed into the different RNA molecules, one complementary to each strand. In practice, only one of the strands is transcribed in any one segment of DNA. The orientation of the promoter indicates which strand is to be transcribed. In prokaryotes, a single RNA polymerase transcribes rRNA, mRNA and tRNA, but in eukaryotes there are three different kinds of polymerases.

The messenger RNA of prokaryotes is ready for translation as soon as it is transcribed. At the beginningof each mRNA is a ribosome binding site, a sequence of nucleotides that binds to a ribosome in such a way that the first codon (AUG) is positioned correctly for translation and the last codon is called stop codon which may be one of three codons UAA, UAG and UGA (Fig. 1). At the other end of mRNA molecule, there is a polyadenine (ploy-A) tail composed of up to 200 adenine residues. It appears that this tail protects mRNA from breakdown by enzymes in the cytoplasm. In prokaryotes ribosomes may attach to the beginning of the mRNA and start translating it into protein while the end of the molecule is still being synthesized on the DNA template. In eukaryotes, on the other hand, the original mRNA transcript must be processed further in the nucleus before the mature mRNA is ready to enter the cytoplasm and participate in protein synthesis.

Fig. (1) Diagram of mRNA molecule to show the site of ribosome and polyadenine tail and start codon

2. Ribosomal RNA (rRNA):

Ribosomes, the organells of protein synthesis, consist of several types of rRNA and bout 70 kinds of polypeptides. In eukaryotes, the production of ribosomes takes place in an area of the nucleus called the nucleolus, where several hundred thousands of

ribosomes are produced per hour. Such rapid production is possible only because an eukaryotic cell's DNA contains up to 600 copies of the ribosomal-RNA genes from which rRNA is transcribed. There are four different kinds of rRNA that participate with the protein in ribosome structure.

A functional ribosome consists of two subunits, one large and one small. When not engaged in protein synthesis, the subunits separate and move around independently. Each may join to a different subunit of the opposite type the next time they participate in protein synthesis. In eukaryotes, the polypeptides of ribosomes are made in the cytoplasm and then pass through the nuclear envelope and enter the nucleolus where the rRNA and polypeptides are assembled into ribosomal subunits. During protein synthesis, interaction occurs between mRNA and rRNA.

3. Transfer RNA (tRNA):

The third kind of RNA that participates in protein synthesis is transfer RNA (tRNA), which carries amino acids to the ribosomes. For each kind of amino acid, there is a specific kind of tRNA molecule that will recognize and transport it. (Amino acids for which there are several different codons have more than one distinct kind of tRNA). Transfer RNA is transcribed from tRNA genes, often arranged in clusters of seven or eight tRNA genes in the same part of DNA molecule.

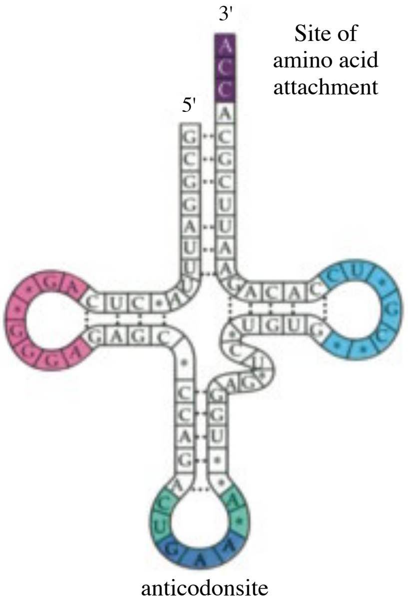


Fig. (2) tRNA molecule

All tRNA molecules have the same general shape parts of the molecule (Fig. 2), fold back in characteristic loops, which are held in shape by basepairing between different areas of the molecule.

There are two sites on tRNA molecule which are important in protein synthesis. The first site is where the amino acid is attached to the molecule. This site consists of the three bases (CCA) at the 3`end of the molecule. The other site is the anticodon site which base-pairs with the appropriate mRNA codon at the mRNA ribosome complex. This temporarily binds the tRNA to the mRNA, allowing the amino acid carried by the tRNA to be incorporated into the polypeptide in its proper place.

The Genetic Code

We have said before that the genetic code represented by a particular sequence of nucleotides in DNA is transcribed to a complementary sequence in triplet on mRNA which goes to the ribosome where it is translated into a particular sequence of amino acids in a polypeptide which makes a particular protein. And now, the question is : what is the number of nucleotides responsible for selecting tRNA molecules which carry each amino acid? Twenty different amino acids are known to take part in the synthesis of proteins. At the same time, there are only four nucleotides involved in the structure of both DNA and RNA. Thus, the genetic "language" must have a four-letter "alphabet". These four nucleotides "letters" must some how make up "words" each of which stands for a particular amino acid. There must be at least 20 different genetic codes to specify the 20 amino acids. The words cannot be only one letter long; because in that case there would be only four possible code words (A, C, G and U) and proteins could contain only four different amino acids. Similarly, the words cannot be just combinations of two nucleotides long, because four letters arranged in all possible combinations of two gives only $4^2 = 16$ different code words, still not enough to specify 20 different amino acids. The four nucleotides arranged in triplets, however, produce $4^3 = 64$ different code words, more than enough to produce a unique code word for each amino acid. The smallest theoretical size for a code word in DNA is, therefore; three nucleotides.

By 1960, there was considerable evidence of a triplet code, but deciding which sequence of three uncleotides coded for which amino acid (called codon) appeared very difficult. By 1965, these codons were derived in table 1. It should be noticed that the codons shown in the table are code words found in RNA, but the DNA code triplets are the compliments of those shown in Table 1, also reveals that the code is degenerate, that is, there is more than one codon for most of the amino acids. Besides, there is codon for the start of protein synthesis (AUG) and three stop codons (UAG, UAA and UAG) at which protein synthesis mechanism stops and give signal.

The genetic code is to the point of termination of poly peptide ehain universal, the same codons code for the same amino acids in all viruses, bacteria, plants, animals and fungi that have been examined. This is a strong evidence that all living organisms on earth now have been originated from common ancestors, and so it seems that the

code must have been established shortly after life originated and has continued almost unchanged for billions of years since this time.

Table (1) Codons of Amino acids
(for reading only)

First base	Second Base				Third base
	U	C	A	G	
U	UUU Phenylalanine	UCU Serine	UAU Tyrosine	UGU Cystenine	U
	UUC Phenylalanine	UCC Serine	UAC Tyrosine	UGC Cystenine	C
	UUA Leucine	UCA Serine	UAA stop	UGA stop	A
	UUG Leucine	UCG Serine	UAG stop	UGG Tryptophan	G
C	CUU Leucine	CCU Proline	CAU Histidine	CGU Arginine	U
	CUC Leucine	CCC Proline	CAC Histidine	CGC Arginine	C
	VUA Leucine	CCA Proline	CAA Glutamine	CGA Arginine	A
	CUG Leucine	CCG Proline	CAG Ghitamine	CGG Arginine	G
A	AUU lsoleucine	ACU Threenine	AAU Asparagine	AGU Serine	U
	AUC lsoleucine	ACC Threenine	AAC Asparagine	AGC Serine	C
	AUA lsoleucine	ACA Threonine	AAA Lysine	AGA Argininc	A
	AUG (START) Methionine	ACG Threonine	AAG Lysine	AGG Arginine	G
G	GUU Valine	GCU Alanine	GAU Asparagine	GGU Glycine	U
	GUC Valine	GCC Alanine	GAC Asparagine	GGC Glycine	C
	GUA Valine	GCA Alanine	GAA Glutamic acide	GGA Glycine	A
	GUG Valine	GCG Alanine	GAG Glutamic acide	GGG Glycine	G

Protein Synthesis

Protein synthesis starts when the mRNA binds to a small ribosomal subunit and the first codon (AUG) is positioned correctly for the initiation of protein synthesis. The AUG codon then base-pairs with the anticodon of tRNA carrying methionine. This methionine eventually becomes the first amino acid in the polypeptide chain. Now a large ribosomal subunit binds to the complex and the reaction of protein synthesis itself can begin (Fig. 3).

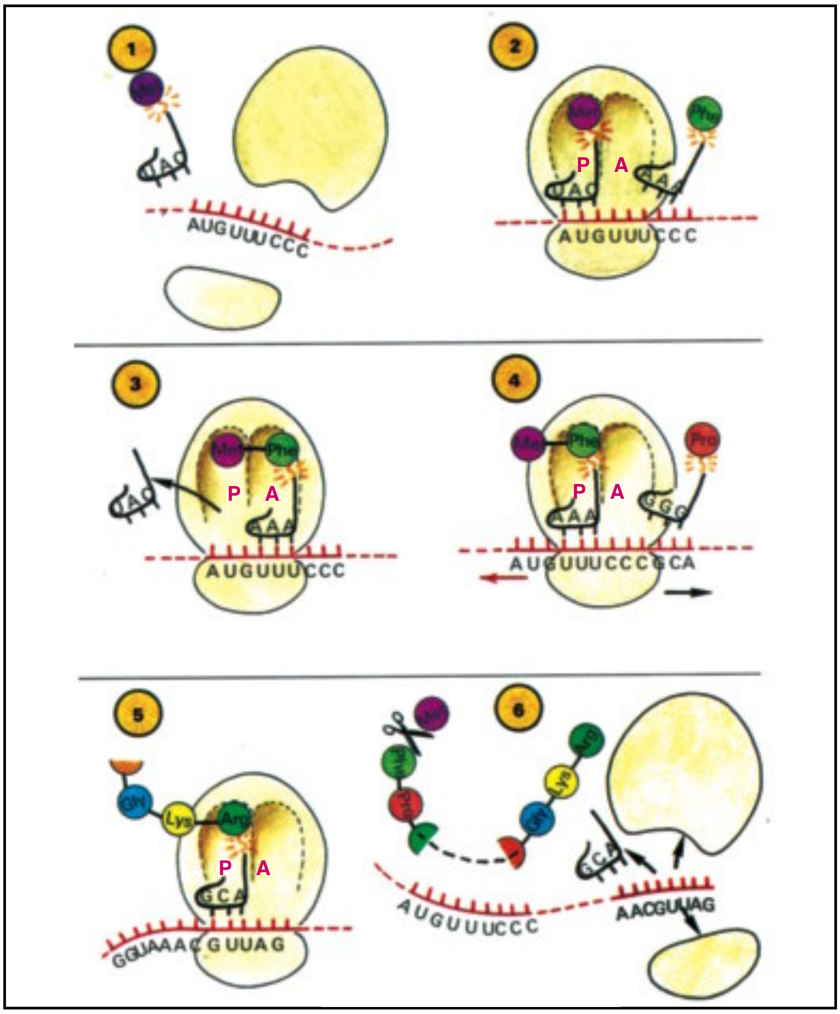


Fig. (3) Steps of protein synthesis

A ribosome has two sites where tRNA can bind. As a result of the events outlined above, the initiation codon, AUG, on the mRNA molecule is positioned at the first of these sites on the ribosome, Peptidyl (P) site. The mRNA codon for the second amino acid is lined up with the second site, the aminoacyl site. From this point, the polypeptide chain elongates by a cycle of three steps.

1. The first step is the binding of the next tRNA to an anticodon complementary to the next mRNA codon. The amino acid carried by this tRNA will be the next amino acid in the polypeptide chain.
2. The second step is the peptidyl transferase reaction, which results in the peptide bond formation. The peptidyl transferase enzyme, which catalyzes the reaction, is an integral part of the large ribosomal unit. This enzyme attaches the first amino acid to the second one by a peptide bond, so that the first tRNA is now empty and the second is holding both amino acids.
3. The third step in the cycle moves the ribosome along mRNA. This brings the next codon to the ribosomes Psite, and the cycle starts over again as the anticodon of the appropriate tRNA binds to the codone, bringing the third amino acid into position at the A site. The growing polypeptide chain is attached to the newly arrived amino acid on this third tRNA and the sequence repeats.

Protein synthesis stops when the ribosome reaches a stop codon on the mRNA. A special protein, called a releasing factor binds to the stop codon and causes the mRNA to leave the ribosome. The ribosomal subunits separate, as the 5`end of the mRNA emerges from the ribosome, it may bind to another small ribosomal subunit which initiates protein synthesis again. Each mRNA molecule typically has from several to over 100 ribosomes attached to it and transcribing its message as they move along. One mRNA with many ribosomes attached to it forms a cluster called a polyribosome or polysome.

Molecular Technology

After the advances in knowing the gene stractur and how protein is synthesized. It is possible now to isolate a desired gene and grow millions of copies of it in the cells of bacteria or yeasts. It is also possible to analyze these copies to determine the nucleotide sequence in this gene and to compare the structures of different genes in the same or different organisms.

Once we have found the sequence of nucleotides we can determine the sequence of amino acids in the corresponding protein. In several cases, it was possible to transfer functioning genes into the cells of plants or animals.

It is possible now to make DNA by order.

In 1979 Khorana produced an artificial gene and introduced it into a laboratory culture of bacteria. Many laboratories are now equipped with "gene machines" that can be programmed to produce short strands of DNA in any desired sequence of nucleotides which can be used in experiments of protein synthesis. By changing the code so as to eliminate particular amino acids from a protein, biochemists can determine how the amino acids affect the function of the protein as a whole.

These achievements are products of the new technology of genetic engineering.

Techniques of molecular technology

Nucleic Acid Hybridization:

When DNA is heated to 100°C, the hydrogen bonds linking the base pairs are disrupted and the two strands of the double helix separate to produce single stranded DNA. Single stranded DNA is unstable and when the temperature is lowered, it tends to stabilize by sticking (or annealing) to another single strand to form a double helix once again. Any two single-stranded chains of DNA or RNA can form double strands provided they have at least short complementary base sequences. The degree of annealing between any two nucleotide strands can be measured by the heat required to separate them again.

The more tightly the strands are bound together, the more heat will be required to separate them.

The ability of single-stranded DNA and RNA to anneal can be used to produce hybrid, or mixed double helices by mixing nucleic acids from two different sources (for instance from two different species of organisms) and then heating thm. When the mixture is allowed to cool, some of the original helices will reform, but many new hybrid double-stranded helices will form, each made up of one strand from each source.

Uses of hybridized DNA

1. DNA hybridization can be used to tell whether a particular gene is present in its genom and in what amount. A single stranded sequence of nucleotides complementary to one strand of the gene in question is prepared; using radio-active nucleotides so that, the sequence is labelled and can easily be identified later. This preparation is then mixed with the unknown sample. The concentration of the gene in the sample is indicated by the rate of formation of radio-activedouble helices.

2. DNA hybridization can be used to determine evolutionary relationships between different species. The closer the evolutionary relationship between two species, the more similar their DNA sequences should be, and therefore the greater the degree of hybridization between them.

Bacterial Restriction Enzymes

It was known that viruses invade certain strains of *E-coli* which are restricted to these strains and cannot grow inside other strains of these bacteria. It was found in the seventies that the resistance strains of bacteria produce enzymes that attack specific nucleotide sequences in the viral DNA and break the DNA into useless fragments. These enzymes were called restriction endonucleases. The question now is why don't these enzymes destroy the bacterium's own DNA? In addition to the restriction endonucleases, each species of bacteria has modification enzymes. The modification enzymes bind to those particular sequences and attach methyl groups ($-CH_3$) to the nucleotides on the bacterial DNA which are similar to the recognetion sites of virues which make the bactarial DNA more resistant to the action of these enzymes.

It was found that resteriction enzyms are spread in micorganisms, and about more than 250 enzymes from defferent strains of bacteria. Each enzyme recognizes a specific sequence of four to seven nucleotides in DNA and cut the DNA at or near this recognition site. (Fig.4)

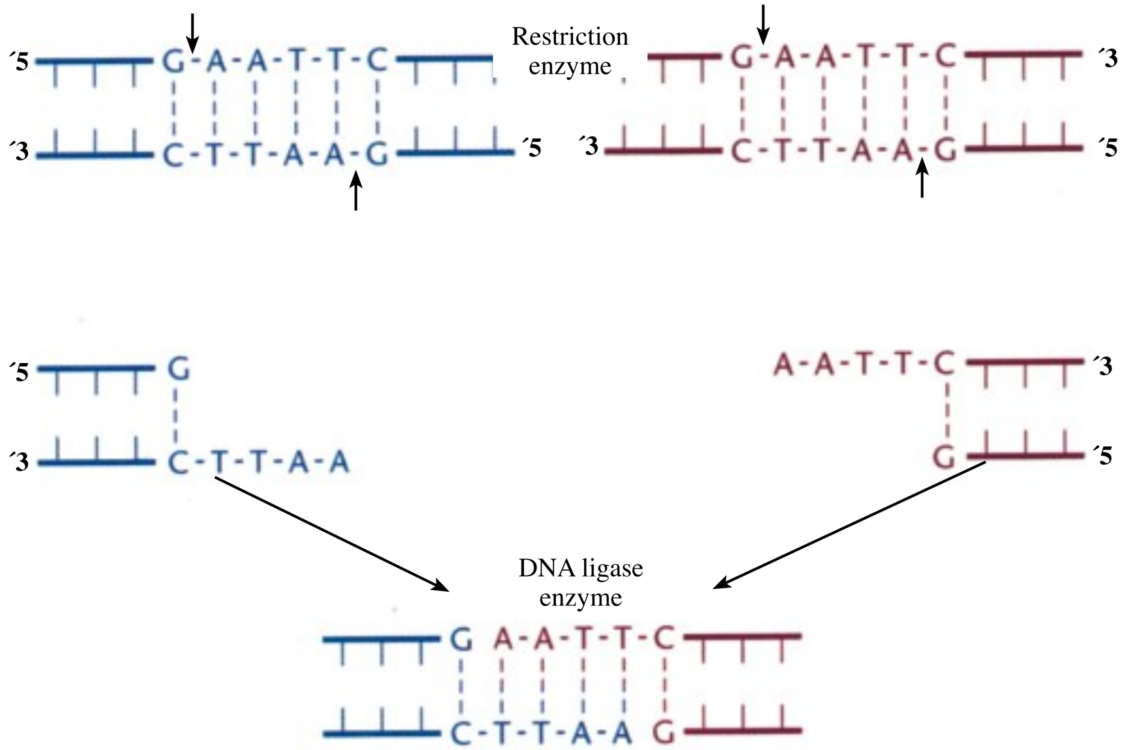


Fig. (4) The role of restriction and DNA ligase enzymes to cut and past two different DNA peices at recognition sites

The sequence of bases on the two strands of DNA at the recognition site are the same when each is read in the 5`→ 3`direction. Each restriction enzyme will cleave DNA from any source (viral, bacterial, plant or animal) as long as that DNA contains one or more copies of its specific recognition sites.

Restriction endonucleases provide a way to cut DNA into pieces with known nucleotides at their ends. Many of them also produce staggered cut ends in which the double helix is left with two single-stranded ends. These are called "sticky ends" because they will base-pair with any other single-stranded end produced by the same restriction endonuclease, and the cut ends can then be joined into a single strand by DNA ligase. In this way, researchers can splice a specific section of DNA into another DNA molecule.

Cloning DNA Sequences

Biologists can produce several identical copies of a gene or piece of DNA (Fig. 5) by splicing it to a molecule that can carry it into a bacterial cell. This carrier may be phage or a plasmid.

To splice a foreign gene or a piece of DNA into a plasmid, samples of the plasmid and the gene (or DNA) of interest are both treated with the same restriction endonuclease to create complementary, single-stranded sticky ends. When the two are mixed, some of the

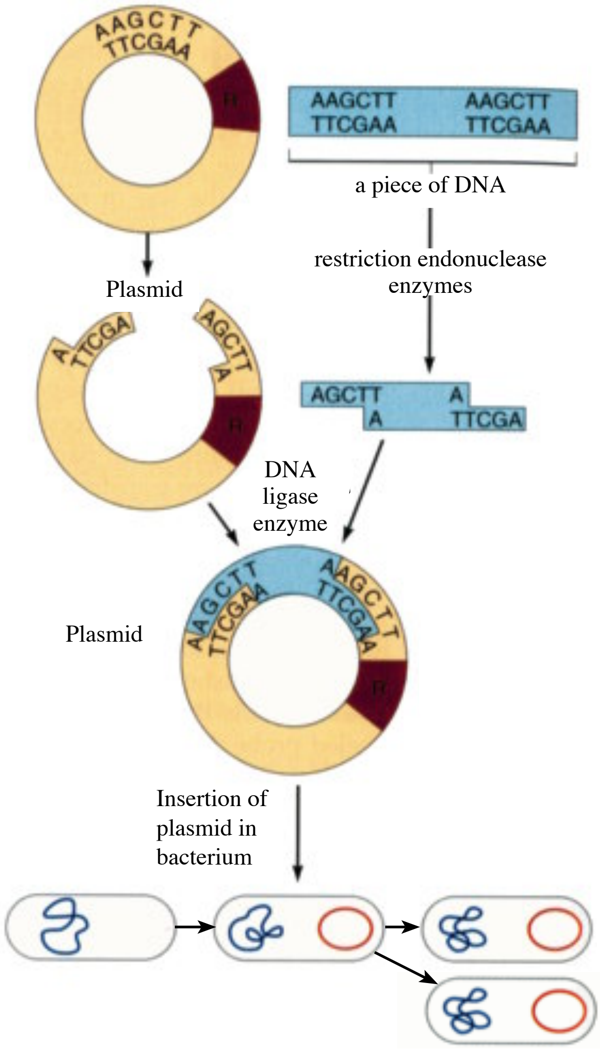


Fig. (5) DNA Cloning

plasmids sticky ends will base-pair with those of the desired gene, and the two can be joined together by DNA ligase.

After that, the prepared plasmids are added to a culture of bacteria or yeast cells which have been treated to make them more permeable to DNA. Some of the plasmids are taken up by cells, and as the cells grow and divide, so they replicate the plasmid along with their own genome. Now, the cells can be broken up and the plasmids recovered. Treatment with the same restriction endonuclease release the cloned gene from the plasmid. The genes and plasmids can then be separated by differential centrifugation. The investigator now has a sizable quantity of identical DNA molecules which can be analyzed to determine their nucleotide sequence, or treated so that they can be transplanted into another cell.

DNA for cloning may be obtained in two ways: cells are broken up and the entire genome cleaved with restriction endonuclease. A mammalian genome treated in this way may produce millions of DNA fragments. These DNA pieces are spliced into plasmids or phages and cloned. Then various selection techniques are used to isolate the DNA sequences desired.

The other way and the better, to obtain DNA for cloning, is to start with cells in which the gene of interest is active. For example, cells in the pancreas produce insulin and the precursors of red blood cells produce hemoglobin. In these cells there is great deal of mRNA carrying the message necessary to make the protein. Investigators can isolate this RNA and use it as a template to make complementary DNA, a process very similar to the replication of DNA. The enzyme that can make DNA on mRNA template is called reverse transcriptase. The enzyme is produced by viruses with RNA genomes which use it to convert their own RNA genomes into DNA that can be joined to hosts DNA genome. Once reverse transcriptase has produced a single strand of DNA its complement can be synthesized by DNA polymerase. The resulting double stranded DNA can then be cloned.

Now, the polymerase chain reaction (PCR) can clone pieces of DNA. This machine uses taq polymerase enzyme which works, at high temperatures. This machine is capable of making many thousand copies of DNA in few minutes.

Recombinant DNA

The last decade or so has seen new accomplishments in the technology of recombinant DNA; the introduction of DNA from one organism into cells of another. Some scientists imagine a time when we will be able to introduce copies of normal genes into human beings whose genes are defective, thereby preventing much suffering and eliminating the need for the treatment of genetic deficiencies. (Obviously this could be a very dangerous technology if used for other purposes, and many people strongly oppose permitting research in this field).

The practical application of recombinant DNA

A) The production of useful proteins on a commercial scale. In 1982, the USA licensed the first recombinant DNA protein-human insulin, a hormone needed daily by millions of people with diabetes. Previously, all the insulin available was extracted from the pancreas glands of cattle and pigs, a long and expensive process.

Althought bacteria-grown insulin is just as expensive, it is better for some patients, who cannot tolerate the slight differences between human insulin and that of other species. With improvements in production methods, bacterial insulin should become less expensive.

B) Researchers have also, developed micro organisms containing the genes for human interferon, proteins that interfere with replication of viruses (particularly viruses with RNA genomes such as those that cause influenza and pliomyelitiys). In the body, interferons are made and released by virus-infected cells, thereby protecting the cells healthy neighbours. It seems that interferons ought to be very useful for treating viral diseases (including some cancers). During the 1970s, the interferon for medical use was laboriously extracted from human cells and so was scarce and very expensive. In the 1980's, drug company research workers introduced 15 human interferon genes into bacteria, and relatively abundant and inexpensive interferons are now available. Preliminary studies using interferons to treat cancer have been disappointing, but this may be due to technical problems that can be overcome.

C) Agricultural researchers will probably soon be able to give crop plants genes for resistance to herbicides and important diseases. Much effort is going into attempts to

isolate and transplant the genes that enable members of legumes to house nitrogen fixing bacteria in their roots. If we can transplant the relevant genes into other crop plants and set them up with bacteria, it would eliminate the need for nitrogen fertilizers. These fertilizers are expensive to produce and apply, and often contribute to water pollution in agricultural areas.

D) Many uses of genetic engineering are still only dreams, but the dreams are coming true much faster than we might expect. Already workers have transplanted a gene from a strain of fruit flies into the embryos of another. The gene was inserted into cells destined to become reproductive organs. When the embryos grow up, they passed on the transplanted gene, which endowed their offspring with ruby-red eyes instead of brown (Since the gene was present only in the reproductive organs of the flies that received transplants, they themselves had brown eyes). Another team of researchers has introduced a gene for growth hormone from rats and humans into mice, who have grown to twice their normal size and also passed the gene on to their offspring.

On the other side, many people worry about what will happen if there is an accident. Suppose a strain of bacteria with a gene for a dangerous toxin were let loose on the world! Many workers feel that the chance of this happening is slight. Although the bacteria used in many recombinant DNA experiments are *Escherichia* coli, a species universally found in the human intestine, the actual strains used in the laboratory have been out of contact with real bodies for thousands of generations. They have evolved in such a way that they can no longer survive outside their test-tube homes.

The human Genome

In the fifties of the last century, the best biological discovery was the proof of Watson and Crick in 1953. It was that, the DNA is double helix strands. After that, scientists started to search all about genes and more discoveries succeeded. The idea of the genome appeared in 1980, the number of human genes was about 450 genes. In the middle of the eighties the number was doubled three times to be 1500 genes. Some of these genes

are the causes for the increase of cholesterol in blood (one reason of heart disease) and some cause cancer diseases. Scientists discovered that there is about 60000 - 80000 genes in the human body which exist in 23 pairs of chromosomes which are known as human genome. Only half of these genes are discovered till now. Chromosomes are arranged according to their sizes from number (1) to number (23), the chromosome (X) is not part of this arrangement as it follows the chromosome Nº (7) in size but it is arranged at the end of chromosomes. From genes which were determined the gene of finger print which is located on chromosome Nº (8), genes of blood groups which are located on chromosome Nº (9), the gene responsible for the formation of insulin and Haemoglobin are situated on chromosome (11), and genes of colour blindness and Haemophilia are situated on chromosome (X).

By continuing the research about genes and genome, to know the structure of the genome, we identified the function and structure of each gene in the human genome.

The uses of the human genome

1. Identifying the genes which cause the rare and common hereditary diseases.
2. Identifying the genes which cause the disabiliby of organs to perform vital activities.
3. Preparing drugs without side effects in the future.
4. Studying the evolution of living organisms by comparing the human genome with genes of living organisms.
5. Improving the offsprings by identifying the defected genes of the fetus before it is born and how to be cured (gene therapy).

Now, we can identify the characteristics of any human on Earth by analysing his hair or sperm to know his genome, thus we can draw a complete picture for his features by analysing one hair from his head.

Questions

1. Choose the correct answer:

1. The ratios of the nitrogenous bases of a nucleic acid of an organism was found to be as follows:

A = 12%   U = 18%   G = 39%   C = 32%

This nucleic acid is.

a) ADN double helix   b) a single strand of DNA

c) tRNA   d) rRNA.

2. The genetic material RNA is found in:

a) rats   b) wheat

c) the virus of AIDS   d) bacteriophage.

3. The codon is a three consecutive nucleotides on:

a) DNA   b) mRNA

c) tRNA   d) rRNA.

4. If the codone is triplet, the probability of the codones of different amino acids will be:

a) 3^3 b) 4^3

c) 3^4 d) 4^2.

5. A polypeptide is formed of 21 amino acids, the least possible number of nucleotides in its RNA would be :

a) 21   b) 42

c) 63   d) 69.

2. The following is a part of a DNA strand.

3′ — A A A T T C C G A T T T A C T — 5′

a) Write down the sequence of its complementary strand.

b) Write down the sequence of its mRNA.

c) Calculate the ratio of $\frac{A + C}{T + G}$ from the double helix.

3. Gene X is formed of 150 pairs of nucleotides. What is the number of the amino acids that constitute the resulting protein?

4. Analysing a genetic material virus gave the following results concerning the ratio of its nitrogenous bases.

G = 32% U = 18% C = 32% A = 18%

What is the kind of nucleic acid this virus has? And why ?

5. In bacteria, the two processes of transcription and translation occur at the same time. This is because there is no nuclear membrane surrounding the genetic material.

a) Both statements are true and there is a relation between both.

b) The two statements are true and there is no relation between them.

c) The two statements are wrong.

d) The first statement is true and the second is wrong.

e) The first statement is wrong and the second is true.

6. Which of the following statements is not true? Why?

1. The two sub-units of ribosomes do not combine except during the translation of mRNA to the corresponding protein.
2. The translation of mRNA occurs through one ribosome only.
3. The mitochondria and ribosome have DNA.

4. The number of tRNA equals the number of the twenty amino acids.

5. The gene is the protein that decides the appearance of the genetic trait.

7. Give reasons for the following:

1. The position of one strand of DNA is opposite to the other.
2. The ligases enzymes plays an important role in the genetic consistency of inheritance of living organisms.
3. The genome of the salamander equals 30 times the human genome, but it represents a smaller number of traits.
4. The ability of bacteria to degrade the viral DNA.
5. The presence of the reverse transcriptase in viruses whose genome is RNA.
6. The genetic code is an evidence for evolution.
7. The viruses have quick mutations.
8. Thousands of ribosomes are built in one hour.
9. The polyadenine tail of mRNA is not translated into amino acids.
10. Proteins are different despite the resemblance of their building units.

8. What is meant by each of the following:

Plasmid - Polyribosome - Release factor - Human genome - The genetic code - Anticodon - Initiation codon - Stop codon.

9. Choose from column B what suites statements in column A.

A	B
1. Deoxyribonucleic enzyme	a) repair defects in DNA.
2. DNA helicase	b) separate DNA strands.
3. DNA polymerase	c) degrade DNA completely.
4. Reverse transcriptase	d) breaks DNA in certain places.
5. Ligase enzymes	e) add new nucleotide in the direction 5`.
6. Restriction endonuclease	f) transcribes mRNA from DNA.
7. RNA polymerase	g) transcribes DNA from RNA.

10. Compare between:

a) DNA and RNA nucleotides.

b) DNA in prokaryotes and eukaryotes.

c) Structural and regulatory proteins.

d) Replicated and recombinant DNA.

11. Most of the studies concerning the discovery of the true genetic material used viruses and bacteria. Explain one of these experiments where the viruses and bacteria were used to prove that the genetic material is DNA and not protein.

12. What is the importance of the human genome?

13. Briefly, explain the steps of protein synthesis starting with the transcription of the genetic information.

تم الطبع بالشروق الحديثة ـ القاهرة
بالمواصفات الفنية الآتية

عدد الصفحات : ١٥٢ صفحة

المقاس : ٥٧ × ٨٢ سم

نوع الورق : لا يقل الداخلى عن ٨٠ جرام والغلاف ٢٠٠ جرام

ألوان الطبع : ٤ لون للداخلى والغلاف

جميع حقوق الطبع محفوظة لوزارة التربية والتعليم
داخل جمهورية مصر العربية

الشروق
الحديثة للطباعة والتغليف
القاهرة : ٨ شارع سيبويه المصرى ـ ت : ٢٤٠٢٣٣٩٩ ـ فاكس : ٢٤٠٣٧٥٦٧ (٠٢)
مدينة العبور ـ المنطقة الصناعية